WD to WGWIDE 2017 (30/08-05/09/2017). ICES HQ

PELAGIC ECOSYSTEM ACOUSTIC-TRAWL SURVEY PELACUS 0317 RESULTS ON MACKEREL, HORSE MACKEREL, BLUE WHITING AND BOAR FISH ABUNDANCE ESTIMATES

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Unión Europea
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EXECUTIVE SUMMARY

The Spanish acoustic-trawl survey PELACUS 0317 was carried out on board R/V Miguel Oliver from 13th March to 16th April, covering the north Spanish waters (Atlantic and Bay of Biscay, ICES Divisions 9a and 8c), together with the southern part of the French continental shelf (8b until 45ºN) from the coast to the 1000 m isobath on a systematic grid with tracks 8 nmi apart and equally spaced.

Acoustic , fishing stations, fish egg counting, microplastic, and apical predators observations were done during day time whilst the oceanographic characterisation was done during night time. A total of 4441 nautical miles were steamed, 1513 corresponding to the survey track. Besides 68 fishing stations and two previous trials for checking equipments, were performed.

Contrary to the conditions found in 2016 when weather and oceanographic conditions were those of the winter time, higher sea surface temperature and primary production would have had an important impact on the fish availability.

Accounting the species assessed in WGWIDE, mackerel was the most important fish, followed by blue whiting. Estimates of horse mackerel was lower than that of the previous year, while boar fish remain at lowest level.

This WD also provides a series of stock descriptors for the period 2013-16, such as centre of gravity, mean depth of the distribution, mean length and weight along the time series, mean length and weight at age and its variability around the overall mean length and weight at age expressed as anomaly (for each age, the difference between the overall mean and the mean for a specific year), or the cumulated abundance and biomass by age group and year. The results of these descriptor are discussed on account ecological considerations.

TECHNICAL SUMMARY

Institution:	INSTITUTO ESPAÑOL DE OCEANOGRAFÍA
Survey name:	PELACUS 0317
Vessel name:	Miguel Oliver (70 mn length, 2x1000 kW diesel-electric
Dates:	12/03/2017-16/04/2017
Area:	NW-Spanish coast, Southern part of the Bay of Biscay (9a-N, 8c and 8b until 45ºN)
Type:	Acoustic-Trawl
Main objective:	Biomass estimation by means of echointegration of the main pelagic fish population present in the surveyed area. Physical, chemical and biological characterisation of the pelagic ecosystem.
Sampling strategy	Systematic grid with random start, tracks 8 nmi apart from 30 to 1000 isobath, in Spanish area, 12 nmi in French waters
Main sampling procedures	EK-60 at 18-38-70-120-200 kHZ acoustic frequencies. 1513 nmi prospected. Only day time
	CUFES, Intake at 5 m depth, 600 l min^{-1}. 3 nmi/sample, 494 samples (sardine, anchovy and mackerel eggs)
	Pelagic fishing stations: 68 and 3 initial trials
	Marine mammals and birds observations (not yet determined)
	Manta trawl hauls (microplastics). 32 tows mostly done at the same time as the fishing tows
	Hydrological characterisation. 128 stations (60 alone, 3 with rosette, 65 with plankton nets)

Personnel (1st leg)

ANTOLÍNEZ BOJ	ANA	GONZÁLEZ GONZÁLEZ	ISABEL CRISTINA
ARMELLES CLIMENT	ISABEL	GUTIÉRREZ MUÑOZ	PAULA
ASTARLOA DÍAZ	AMAIA	HERNÁNDEZ GONZÁLEZ	ALBERTO
CARRERA LÓPEZ	PABLO	LOPEZ DÍAZ	EDUARDO
CORDOBA SELLES	PILAR	OÑATE GARCIMARTÍN	MARÍA DOLORES
DÍAZ CONDE	PAZ	OTERO PINZÁS	ROSENDO
DÍEZ GARCÍA	IRENE PILAR	PEREIRA PINTO	ESTEFANÍA
DOMÍNGUEZ PETIT	ROSARIO	POUSA FERNÁNDEZ	PEDRO
FERNÁNDEZ LAMAS	ANGEL	RABANAL CARBALLIDO	IRENE
GAGO PIÑEIRO	JESÚS MANUEL	SÁNCHEZ BARBA	MARÍA
GÓMEZ GONZÁLEZ	ANTONIO	SANCHO MARTÍNEZ	PAULA

2nd leg

ASTARLOA DÍAZ	AMAIA	IGLESIAS GARCÍA	MARÍA LUISA
BLANCO GINER	MARIA DE LOS ANGELES	LLEVOT SÁNCHEZ	Mª JESÚS
CARRERA LÓPEZ	PABLO	LLOPE PERI	MARCOS
CARRETERO PERONA	OLGA	LOPEZ DÍAZ	EDUARDO
DÁVILA RODRÍGUEZ	XABIER	MUÑOZ DE LOS REYES	ISABEL
DÍEZ GARCÍA	IRENE PILAR	NAVARRO RODRÍGUEZ	MARIA ROSARIO
DUEÑAS LIAÑO	CLARA	OÑATE GARCIMARTÍN	MARÍA DOLORES
FERNÁNDEZ LAMAS	ANGEL	OTERO PINZÁS	ROSENDO
GONZÁLEZ GONZÁLEZ	ISABEL CRISTINA	SÁNCHEZ BARBA	MARÍA
GUTIÉRREZ MUÑOZ	PAULA	SOLLA COVELO	ANTONIO JOSÉ
HERNÁNDEZ GONZÁLEZ	ALBERTO	VARELA ROMAY	JOSÉ

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Other collaborators	Isabel Riveiro Izaskun Preciado Gonzalo González Bueno

INTRODUCTION

The Spanish acoustic-trawl times series PELACUS started in 1991 when R/V Cornide de Saavedra was rebuilt and a new EK-500 was also purchased. Since that and until 1996, all cruises were carried out on board this vessel except that of 1995, called IBERSAR, which has been undertook on board R/V Noruega. In 1997 the series changed from R/V Cornide de Saavedra to the new R/V Thalassa (TH), a French/Spanish research vessel specially conceived for fish surveys.

This vessel was also used for the French acoustic survey (PELGAS). Survey strategy methods and analysis were established at the Planning Group for Acoustic Surveys in ICES Sub-Areas 8 and 9 met for the first time in 1986. Since 1998 the Planning Group, only attended until then by Spanish and Portuguese members, incorporated French scientists. As a first joint recommendation, the Planning Group agreed that acoustic data will be only recorded during day time, living the night time available for physical, chemical and plankton characterisation of the water column. This recommendation was implemented in 1998. In 2000, under the frame of the DG FISH, PELASSES project started, and the spring acoustic surveys incorporated the Continuous Underwater Fish Egg Sampler (CUFES) together with the routinely collection of other systematic measurements (SSS, SST, Flourometry, CTD+rossete casts, plankton hauls to determine primary production or dry weight at different sizes among other biological descriptors of the water column, etc.). In addition, the 120 khz frequency started to be used to help discriminate between different fish species. During this period, acoustic estimates were also provided for non commercial species such as bogue or boar fish. In 2007, a new team used the survey as a platform to obtain data on presence, abundance and behaviour of top predators (marine mammals and seabirds). Since 2007 data are also routinely collected on floating litter (type, number and position) and on other human pressures such as fishing (number of boats, type, activity, etc.).

Since the beginning of the time series (1982), biological data (length, weight, sex, maturity, etc.) and samples have been taken from individual fish taken by the hauls to provide biological data and to construct length-weight and age-length relationships needed for the assessment of first sardine and later, all the other target species. Fish stomachs have also been routinely examined to quantify the trophic relationships between species and isotope analysis of muscle of sardine and anchovy have been also carried out the study their trophic position.

Overall the evolution of this time series made it an essential platform for integrated data collection following the requirements posed by the Ecosystem Approach to Fisheries Management (EAFM), the Marine Strategy Framework Directive (2008/56/CE) and the revised CFP .

In 2013 R/V is substituted by the Spanish vessel Miguel Oliver (MO), built in 2007. In addition the surveyed area was extended from the 200 m isobath to the 1000 m one in order to make available the bulk of the blue whiting distribution.

On the other hand, both vessels , TH and MO have similar technical characteristics, as show in the following table:

	Thalassa	Miguel Oliver
Length	73.65 m	70.00 m
Width	14.90	14.40 m
Engine type	Diesel-electric	Diesel-electric
Engine power	2000 kW	2 x 1000 kW
Propeller	Fixed blades	Fixed blades
Tonnage	2803 GRT	2495 GRT
Propeller rpm at 10 knots	99	130

Table 1.: Main characteristics fro R/V Thalassa (left) and Miguel Oliver (right).

Intercalibration done in 2014 (acoustic and fishing trawl devices) gave rather similar results for both vessels although a slight difference between fishing gear performance was noticed. That used by R/V Miguel Oliver had a small rockhooper which makes accessible much fish located close to the sea bed (such as demersal species together with more horse mackerel) than that of the R/V Thalassa. In order to make comparable both fishing gears, the rockhooper was substituted in 2015 by a footrope chain, similar to that of the R/V Thalassa.

On the other hand, triennial egg survey for sardine spawning stock biomass using daily egg production method, SAREVA 0417, was undertake at the same time as PELACUS. In order to get a similar spatial coverage, both vessels reached up to 45ºN in French waters. Therefore, during PELACUS, the French shelf until 45ºN was covered using the same acoustic track as for PELGAS, the acoustic time series carried out by Ifremer.

This WD provides acoustic estimates, distribution and mean size for five of the eleven main pelagic species found in northern and northwestern Spanish waters (mackerel, horse mackerel, blue whiting, boar fish and chub mackerel).

OBJECTIVES

Main objective of this survey was to achieve a biomass estimation by echointegration of the main pelagic fish distributed in the Spanish Cantabrian and NW waters (sardine, anchovy, horse mackerel, mackerel, blue whiting, bogue, boar fish, chub mackerel). Together with this, the following objectives were also foreseen:

- Determine the distribution area and density of the main fish species
- Determine the main biological characteristics (length, sex, maturity stage and age) of the main fish species
- Estimate the relative abundance and distribution area of sardine and anchovy eggs by means of CUFES
- Estimate the adults parameters needed to apply the Daily Egg Production Method to sardine. To achieve this objective, de survey has also cover the southern part of the French contiental shelf, up to 45ºN..
- Characterise the main oceanographic conditions of the surveyed area
- Determine the distribution pattern, taxonomic diversity and dry biomass by size classes of the plankton population presented in the surveyed area.

- Determine the natural abundance of N15 in sardine, anchovy and mackerel and their trophic position.
- Determine the distribution area and density of apical predators
- Determine the distribution area and density of marine microplastics litter

MATERIAL AND METHODS

The methodology was similar to that of the previous surveys (see Iglesias et al. 2010 for further details). Survey design consisted in a grid with systematic parallel transects with random start, separated by 8 nm, perpendicular to the coastline, covering the continental shelf from 30 to 1000 m depth and from Portuguese-Spanish border to the Spanish -French one. (Figure 1). In addition the southern part of the French shelf was prospected following the same tracks designed for the French acoustic survey PELGAS (i.e. parallel tracks, 12 nmi apart). A second objective is to compare results obtained during PELACUS (mid April) with those to be obtained in the same area during PELGAS (mid May).

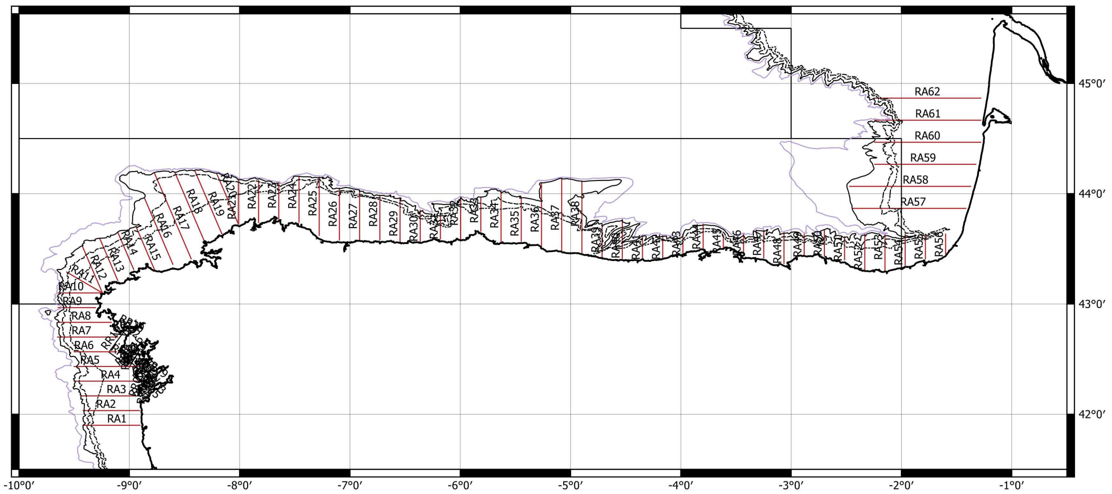


Figure 1 Survey track

The backscattering acoustic energy from marine organisms is measured continuously during daylight. Pelagic trawls are carried out whenever possible to help identify the species (and size classes) that reflect the acoustic energy. A continuous underwater fish egg sampler with an internal water intake located at 5 m depth is used to sample the composition of the ichthyoplankton while trained observers record marine mammal, seabird, floating litter and vessel presence and abundance. At night, data on the hydrography and hydrodynamics of the water masses are collected via the deployment of rosettes and conductivity, temperature and depth sensors. Information on the composition, distribution and biomass of phytoplankton and zooplankton is derived from the analyses of samples taken by plankton nets.

Sampling procedures

Acoustic

Acoustic equipment consisted on a Simrad EK-60 scientific echosounder, operating at 18, 38, 70, 120 and 200 kHz. All frequencies were calibrated according to the standard procedures (Foote et al

1987). The elementary distance sampling unit (EDSU) was fixed at 1 nm. Acoustic data were obtained only during daytime at a survey speed of 8-10 knots. Data were stored in raw format and post-processed using SonarData Echoview software (Myriax Ltd.) (Higginbottom et al , 2000). All echograms were first scrutinized and also background noise was removed according to De Robertis and Higginbottom (2007). Fish abundance was calculated with the 38 kHz frequency as recommended at the PGAAM (ICES 2002), although echograms from 18, 70, 120 and 200 kHz frequencies were used to visually discriminate between fish and other scatter-producing objects such as plankton or bubbles, and to distinguish different fish species according to the strength of their echo at each frequency. The 18, 70, 120 and 200 kHz frequencies have been also used to create a mask allowing a better discrimination between fish species and plankton. The threshold used to scrutinize the echograms was –70 dB. The integration values were expressed as nautical area scattering coefficient (NASC) units or s_A values (m^2 nm^{-2}) (MacLennan et al., 2002).

Main echosounder settings are shown in table 2

Transducer power	2000/2000/1000/200/90 W for 18/38/70/120/200 kHz
Pulse duration	1.024 ms
Ping rate	Maximum, in case of ghost echo-bottom, change to time interval starting at 0.30 ms
Range (echograms, files)	200 m in shallower area (i.e. depth<100m); 400 when depth is between 100-200m; and 1000 when depth is>400m

Table 2: Main echosounder settings.

Acoustic tracks were steamed at 10 knots.

Fishing stations

Fishing stations are used for both NASC allocation and length analysis. Therefore, they were located on account the results obtained during the acoustic prospection (i.e. oportunistic accounting the echotraces).

Two fishing gears were used. An adaptation of a “grandes mailles”, with a vertical opening of about 20 m and around 30 m horizontal one, was used as main fishing gear. As general rig, 400 kg of clump weight were put at each side of the set back (2 m lower wing). Dyneema bridles (wings) had 100 m. Besides a set of Apollo polyice doors (Thyborøn) wer used. Gear performance was controlled using a cabled Simrad Sonar 25/20 net sounder. Close to the cod-end a MARPORT Trawl speed Exploreer SPE155 with the Scala system was placed in order to measure the flux close to the codend in order to ensure that both flux at high towing speed (I.e. 4.5-5 knots) is good and no fish school is escaping below the footrope. Besides, a *gloria* 352 has been used in shallower waters. The performance of this fishing year was also good, although the vertical opening was 5-4 m lower than that of the “grandes mailles”.

CUFES

CUFES system uses an internal pumping system with the intake located at 5 m depth. The sea water goes first to a tank of about $1m^3$ before to be pumped towards the concentrator.

Samples from CUFES were collected every three nmi while acoustically prospecting the transects. Once the sample is taken it is fixed in a buffered 4% formaldehyde solution. Anchovy and sardine eggs are sorted out and counted before being preserved in the same solution. The remaining ichthyoplankton (other eggs and larvae) are also preserved in the same way. Information on horse mackerel and mackerel (qualitative) was also recorded.

Plankton and hydrological characterisation

Continuous records of SSS, SST and flourometry are taken using a SeaBird Thermosalinograph coupled with a Turner Flourometer. Plankton and CTD and bottle rosette for water samples casts are performed at night. Five stations are placed over the transects, which are those of the acoustic prospection but that are extended onto open waters until the 1000-2000 m isobaths. The stations are evenly distributed over the surveyed area at a distance of 16-24 nmi.

Plankton was sampled using several nets (Bongo, WP2 and CalVet). Fractionated dried biomass at 53-200, 200-500, 500-1000 and >2000 µm fractions was calculated together with species composition and groups at fixed strata from samples collected at the CTD+bottle rosette carousel (pico and nanoplankton, microplankton and mesozooplankton). For this purpose, FlowCAM, LOPC and Zoo-Image techniques were used.

Water samples were stored at -20°C for further dissolved nutrients analysis (NO_3, NO_2, P, NH_4^+, SiO_4).

Top predator observations

Three observers placed above the bridge of the vessel at a height of 16 m above sea level work in turns of two prospecting an area of 180° (each observer cover a field of 90°). Observations are carried out with the naked eye although binoculars are used (7x50) to confirm species identification and determine predator behaviour. Observations are carried out during daylight while the vessel prospects the transects and while it covers the distance between transects at an average speed of 10 knots. Observers record species, number of individuals, behaviour, distance to the vessel and angle to the trackline and observation conditions (wind speed and direction, sea state, visibility, etc.). Observers also record presence, number and type of boats and type, size and number of floating litter. The same methodology is used on the PELGAS surveys and both observer teams shared a common database.

Marine Microplastic Litter characterisation

A "manta net neuston sampler" was used. This trawl device has a collector of 350µm. Tows were performed for 15 min at 4 knots speed. The samples were evenly distributed along the surveyed area.

Fish Biological sampling

Catches from fishing trawl hauls were sorted and weighted. All fish species were measured (total length, 1cm classes for all species except clupeids measured at 0.5 cm). When needed, random subsamples of 80-200 specimen were taken. For the main species an additional biological sampling was done for weight, age, sex, maturity stage analysis, complemented by stomach contents analysis (sardine and anchovy); N^{15} isotope analysis (sardine, anchovy and mackerel); sampling for gonad microscopic maturity analysis (mackerel); and, sampling for estimation of fecundity adult parameters (sardine). Besides, specific sampling was also done on horse mackerel for genetic purposes and also on this specie and mackerel for fecundity purposes, in coordination with the triennial mackerel egg surveys.

Data analysis

NASC Allocation

Two pelagic gears have been used to identify the species and size classes responsible for the acoustic energy detected and to provide samples. Choice of net was also dependant on the availability of enough unobstructed ground for the net to be deployed and recovered and for effective fishing to occur. Haul duration is variable and ultimately depends on the number of fish that enters the net and the conditions where fishing takes place although a minimum duration of 20 minutes is always attempted. The quality of the hauls for ground-truthing of the acoustic data was classified on account of weather condition, haul performance and the catch composition in numbers and the length distribution of the fish caught as follows (table 3):

	0	1	2	3
Gear performance Fish behaviour	Crash	Bad geometry Fish escaping	Bad geometry No escaping	God geometry No escaping
Weather conditions	Swell >4 m height Wind >30 knots	Swell: 2 -4 m Wind: 30-20 knots	Swell: 1-2m Wind 20-10 knots	Swell <1 m Wind < 10 knots
Fish number	total fish caught <100	Main species >100 Second species <25	Main species > 100 Second species< 50	Main species > 100 Second species > 50
Fish length distribution	No bell shape	Main species bell shape	Main species bell shape Seconds: almost bell shape	Main species bell shape Seconds: bell shape

Hauls considered as the best representation of the fish community for a specific area were used to allocate NASC of each EDSU within this area when no direct allocation was feasible. This process involved the application of the Nakken and Dommasnes (1975, 1977) method for multiple species, but instead of using the mean backscattering cross section, the full length class distribution (1 or 0.5 cm length classes) has been used, as follows:

$$NASC_l = NASC \cdot \left(\frac{\sigma_{l,\rho}}{\sigma_\rho}\right)$$

where *NASC* is the total backscattering energy to calculate densities by length, $NASC_l$ is the proportion of the total *NASC* which can be attributed to length group l for a particular fish species. $\sigma_{l,p}$ is the backscattering cross-section at length l for a particular species at length l multiplied by the proportion of (p_l) of length of this particular species on the overall catch and σ_p is the sum of all $\sigma_{l,p}$ for all species,

$$\sigma_{l,\rho} = \rho_l * \sigma_l$$

$$\sigma_\rho = \sum_l \sigma_{l,\rho}$$

finally $\sigma_{l,}$ is backscattering cross-section (m^2) for a fish of length l for a particular species and is computed as follows:

$$\sigma_l = \frac{l^{\left(\frac{m}{10}\right)} * 10^{\left(\frac{b_{20}}{10}\right)}}{4 * \pi}$$

This is computed from the formula TS =20 logL_T+ b_{20} (Simmonds and MacLennan, 2005), where L_T is the length class . The b_{20} values for the most important species present in the surveyed area are shown in following table:

Sp	b_{20}	Ref	Observations	Other b_{20}	Ref.
PIL	-72.6	Degnbol et al., 1985	TS for clupeids	-71.2 -70.4 -74.0 -72.5	ICES ,1982 Patti et al., 2000 Hannachi et al., 2005 Georgakarakos et al., 2011
ANE	-72.6	Degnbol et al., 1985	TS for clupeids	-71.2 -76.1 -71.6 -74.8	ICES 1982 Barange et al., 1996 Zhao et al., 2008 Georgakarakos et al., 2011
HKE	-67.5	Foote et al., 1986; Foote, 1987		-68.5 -68.1	Lillo et al., 1996 Henderson, 2005; Henderson and

					Horne, 2007
BOG	-67.5	Foote et al., 1986	Adapted from gadoids		
BOC	-66.2	Fässler et al., 2013			
MAC	-84.9	Edwards et al., 1984; ICES, 2002		-86.4 -88.0	Misund and Betelstad, 1996 Clay y Castonguay, 1996
HOM	-68.7	Lillo et al., 1996		-68.15 -66.8 -66.5/-67.0(*)	Gutiérrez and McLennan, 1998 Barange et al. (1996) Georgakarakos et al., 2011
VMA	-68.7	Lillo et al., 1996	Adapted from HOM;l (Sawada, com. pers.)	-70.95	Gutiérrez and McLennan, 1998
WHB	-65.2	Pedersen et al., 2011			

* day and night respect.

Table 4.- b_{20} values from the length target strength relationship of the main fish species assessed in PELACUS survey (WHB is blue whiting; MAC-mackerel; HKE- hake; HOM- horse mackerel; PIL-sardine; JAA-blue jack mackerel (*Trachurus picturatus*); BOG-bogue (*Boops boops*); VMAS-chub mackerel (*Scomber colias*); BOC-board fish (Capros aper); and HMM-Mediterranean horse mackerel (Trachurus mediterraneus))

When possible, direct allocation was also done, accounting for the shape of the schools and also the relative frequency response (Korneliussen and Ona, 2003, De Robertis et al, 2010). Due to the aggregation pattern found in the surveyed area, fish schools were extracted using the following settings:

Sv threshold	-60 dB for all frequencies
Minimum total school length	2 m
Min. total school height	1 m
Min. candidate length	1 m
Min. candidate height	0.5 m
Maximum vertical linking distance	2.5 m
Max. horizontal linking distance	10 m
Distance mode	Vessel log
Main frequency for extraction	120 kHz

Table 5: Main morphological and backscattering energy characteristics used for schools detection

For all school candidates, several of variables were extracted, among them the NASC (s_A, m^2/nmi^2) together with the proportioned region to cell (ESDU, 1 nmi) NASC and the s_V mean and s_V max and geographic position and time. PRC_NASC values were summed for each ESDU and distances were referenced to a single starting point for each transect. Results for 38 and 120 kHz were compared. Besides, the frequency response for each valid school (i.e. those with length and s_V which allows them be properly measured) was calculated as the ratio $s_{A(fi)}/s_{A(38)}$, being f_i the s_A values for 18, 120 and 200 kHz.

Echointegration estimates

Once backscattering energy was allocated to fish species, the spatial distribution for each species was analysed taking into account both the NASC values and the length frequency distributions (LFD) to provide homogeneous assessment polygons. These are calculated as follows: an empty track determine the along-coast limit of the polygon, whilst three consecutive empty ESDU determine a gap or the across-coast limit. Within each polygon, the LDF is analysed.

LFD were obtained for all positive hauls for a particular species (either from the total catch or from a representative random sample of 100-200 fish). For the purpose of acoustic assessment, only those LFD which were based on a minimum of 30 individuals were considered. Differences in probability density functions (PDF) were tested using Kolmogorov-Smirnov test. PDF distributions without significant differences were joined, providing a homogeneous PDF strata. Spatial distribution was then analysed within each stratum and finally mean s_A value and surface (square nautical miles) were calculated using a GIS based system (Q-gis). These values, together with the length distributions, are used to calculate the fish abundance in number as described in Nakken and Dommasnes (1975) (see previous section for further details). Estimates for each species was carried out on each strata (polygon) using the arithmetic mean of the backscattering energy (NASC, s_A) attributed to each fish species and the surface expressed in square nautical miles using the following formula:

$$\rho_l = \frac{NASC_l}{\sigma_l}$$

$$N_l = \rho_l * A_p$$

where ρ_l is the areal density of fish (numbers per square nautical mile in length group l and the total number for length group l (N_l) within each strata is calculated the product ρ_l of times the total area of the strata (A_p)

Numbers were converted into biomass using the length weight relationships derived from the fish measured on board. For purposes of comparison, results are given by ICES Sub-Divisions (9aN, 8cW, 8cEw , 8cEe and 8b)

Otoliths are taken from anchovy, sardine, horse mackerel, blue whiting, mackerel and hake (*Merluccius merluccius*) in order to determine age and to obtain the age-length key (ALK) for each species and area.

Centre of gravity

For each main specie, a centre of gravity (Woillez et al. 2007) was calculated as a weighted average of each sample location (allocated NASC value as weighting factor). Due to the particular topography of the NW Spanish area, instead longitude and latitude, we have used depth and a new variable called "distance from the origin" calculated as follows:

- Locations below 43º10 N: distance is calculated as (Lat-41.5)*60, being *Lat* the latitude of the middle point of any particular EDSU within this region.
- Location between 43º10' N and 8ºW (i.e. NW corner): distance is calculated as $((I.Lat-43.18333)^2+(I.Lon*(\cos(I.Lat*pi()/180))-6.714441)^2)^{0.5})*60+(43.1833-41.5)*60$, being *I.Lat* and *I.Lon* the coordinates at which a normal straight line from middle point of any particular EDSU within this region intercepts a line defined by the following geographical coordinates: 43º11N-9º12.50'W and 43º39.50'N-8º06'W.
- Location between 8ºW and the Spanish-French border: distance is calculated as 158.329+(Lon+5.8755324052)*60, being *Lon* the corrected longitude (longitude multiplied by the cosine of the mean latitude).

RESULTS

The survey started on 13th March and ended on 16th April. A total of 4441 nautical miles were steamed, 1513 of them corresponding to the survey track. Weather conditions were better than those of the previous year, although the survey was stopped for 2.5 days due to bad weather conditions in the NW part (deep low depression with swells up to 5-7 m height) and another day, due to westwards winds up to force 8 in the Cantabrian sea.

Main oceanographic conditions

Although CTD casts were still not analysed, surface continuous records on salinity, temperature and fluorometry are available. Figure 2 shows sea surface temperature along the surveyed area (from south Galicia in mid March to south France in mid April). Higher temperatures were recorded at both inner parts, with the coldest waters located at the NW corner. Comparing these values with those obtained last year (boxplots bottom figure 2), sea surface temperature was significant different in all areas but 8cEe (inner part of the Bay of Biscay), being higher in 2017. This difference would have affected the spawning activity of mackerel (see mackerel section below).

Concerning salinity, as expected, the influence of river runoff are mainly located in southern area (9a) and at the inner part of the Bay of Biscay. No significant changes, in relation to 2016 data, were observed in these areas while in mid Cantabrian sea waters were saltier than in 2016 (figure 2.b)

Changes were also significant for fluorometry when comparing results obtained in 2016 and 2017 in the Cantabrian Sea, being higher the present years. For the western areas, although higher to, there weren't significant. For 2017, highest primary production was located in the Cantabrian sea, in coincidence with the greater fish biodiversity (figure 2c). Again, such increase in primary production accomplished a higher mackerel egg production from 2016 to 2017, although the spawning biomass remained in both years at high level.

Fishing stations

Without including the trawl hauls done at the beginning of the survey for checking and setting up purposes, 68 fishing station were performed. Figure 3 shows the location and the catch composition in number of each of them.

This year a new device has been added in order to reach a finer control on the fishing performance. The new Marport© Speed Explorer SPE155 has been near the codend. Together with an echogram and depth, this device is able measure flow, thus giving and indication of the water speed at this part of the fishing gear in relation to the towing speed. This allows the performance of the gear in relation to the real flow be measured. Besides, the echogram gives a measure of the number of schools that escape below the footrope of the gear. The scrutinity of these sensors are done by the new software Scala. An example is given in figure 4.

Most of the trawl haul stations were done using a 63.5/51 pelagic gear (20x35 m of vertical and horizontal opening respectively). In shallower water a Gloria HOD 352 (15x35 m of vertical and horizontal opening respectively) was used. In both cases a pair of pelagic doors Apollo PolyIce, 790 kg weight and surface of 3.5 m^2 were used, being then changed by a bigger pair with 1300 kg and 4 m^2.

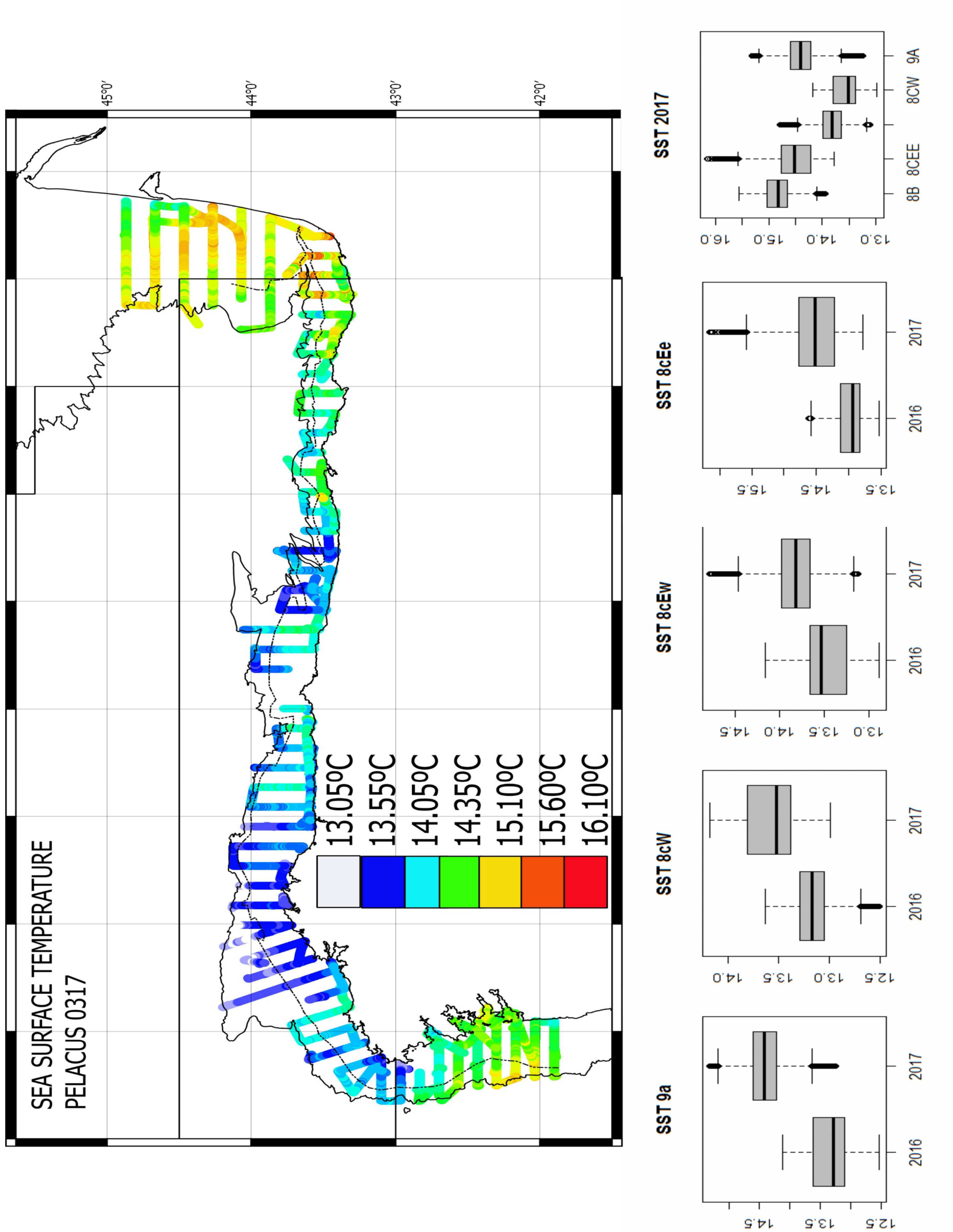


Figure 2a: Sea surface temperature during PELACUS 3017

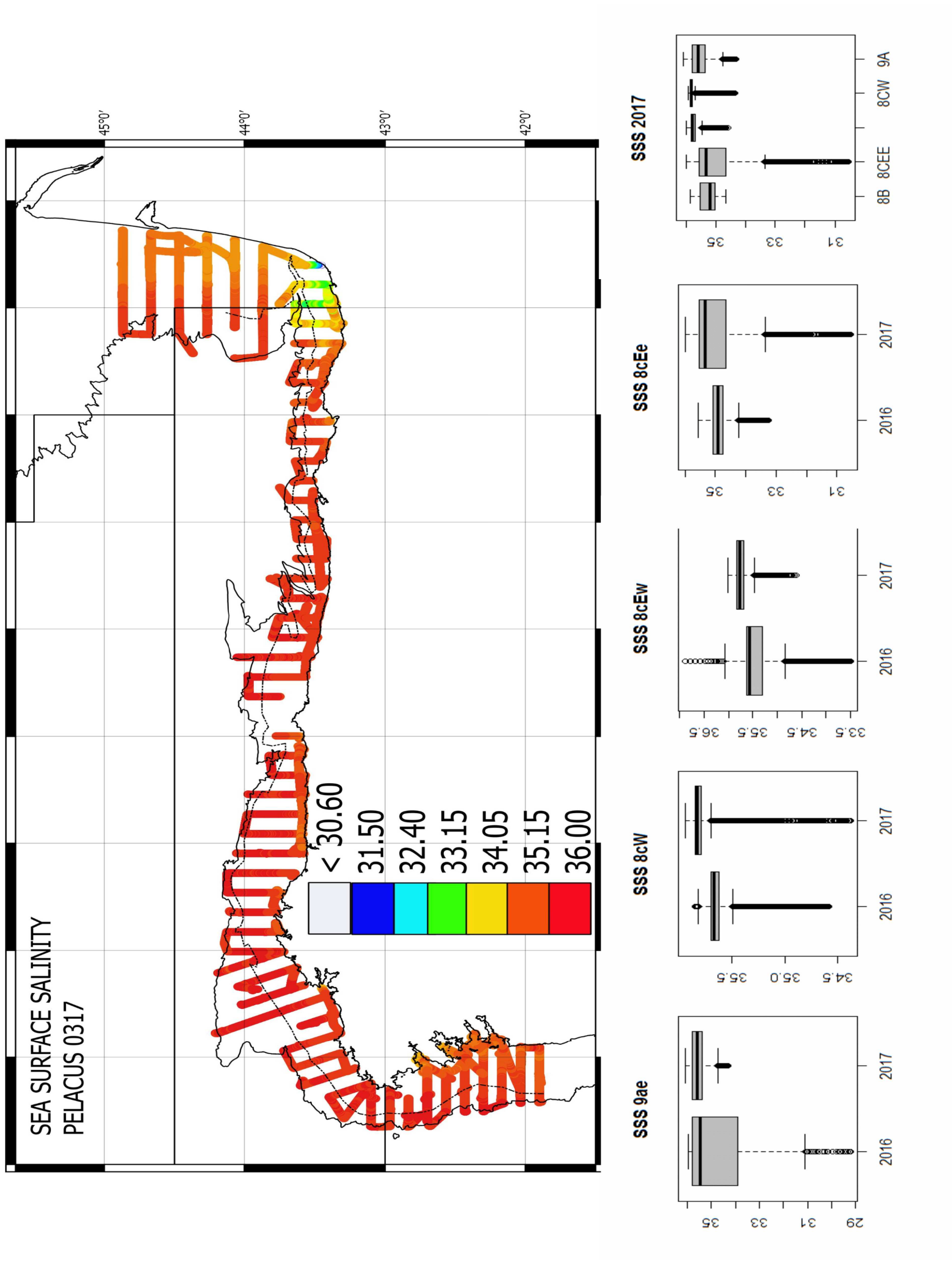


Figure 2b: Sea surface salinity during PELACUS 3017

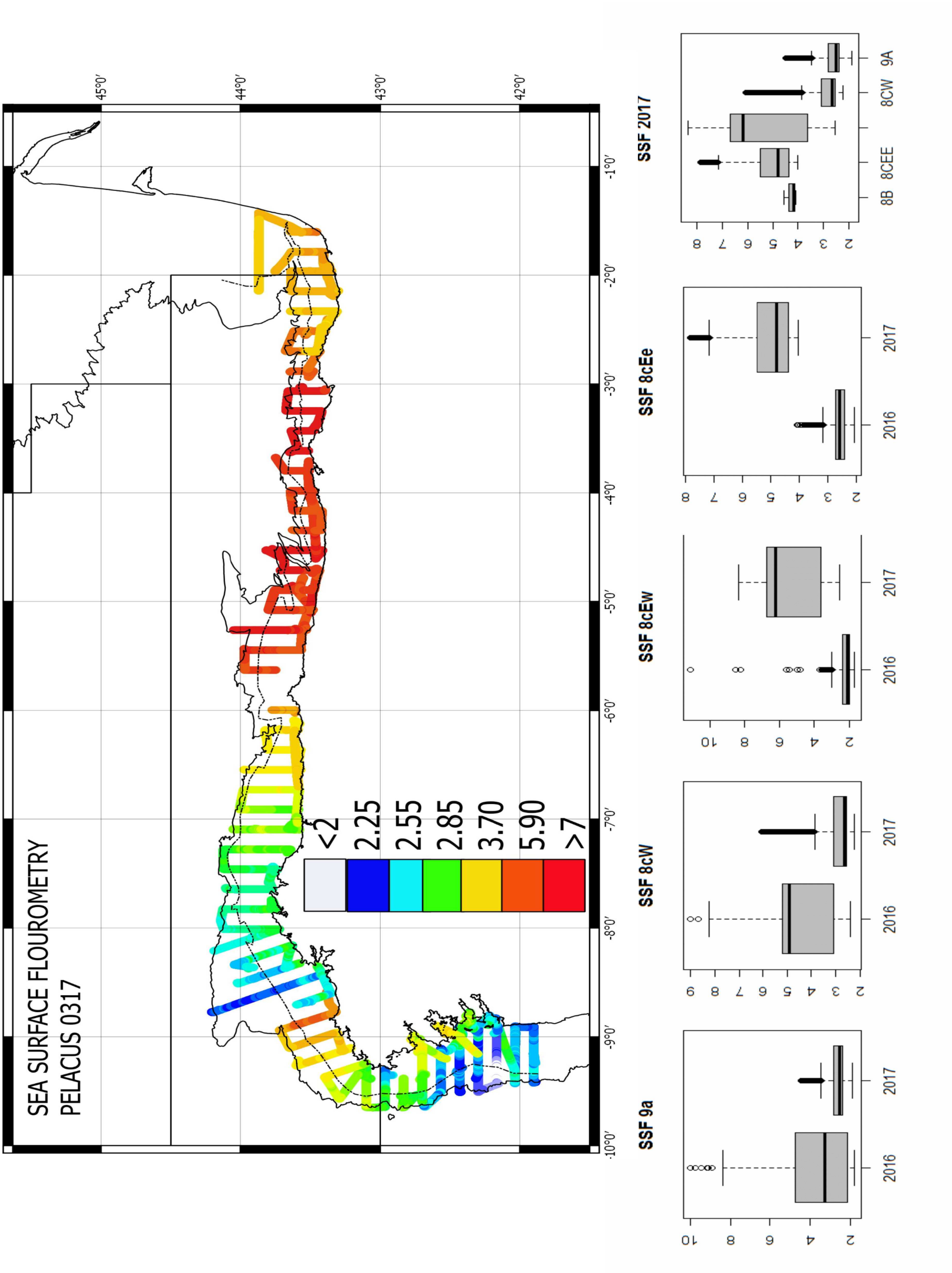


Figure 2a: Sea surface flourometry during PELACUS 3017

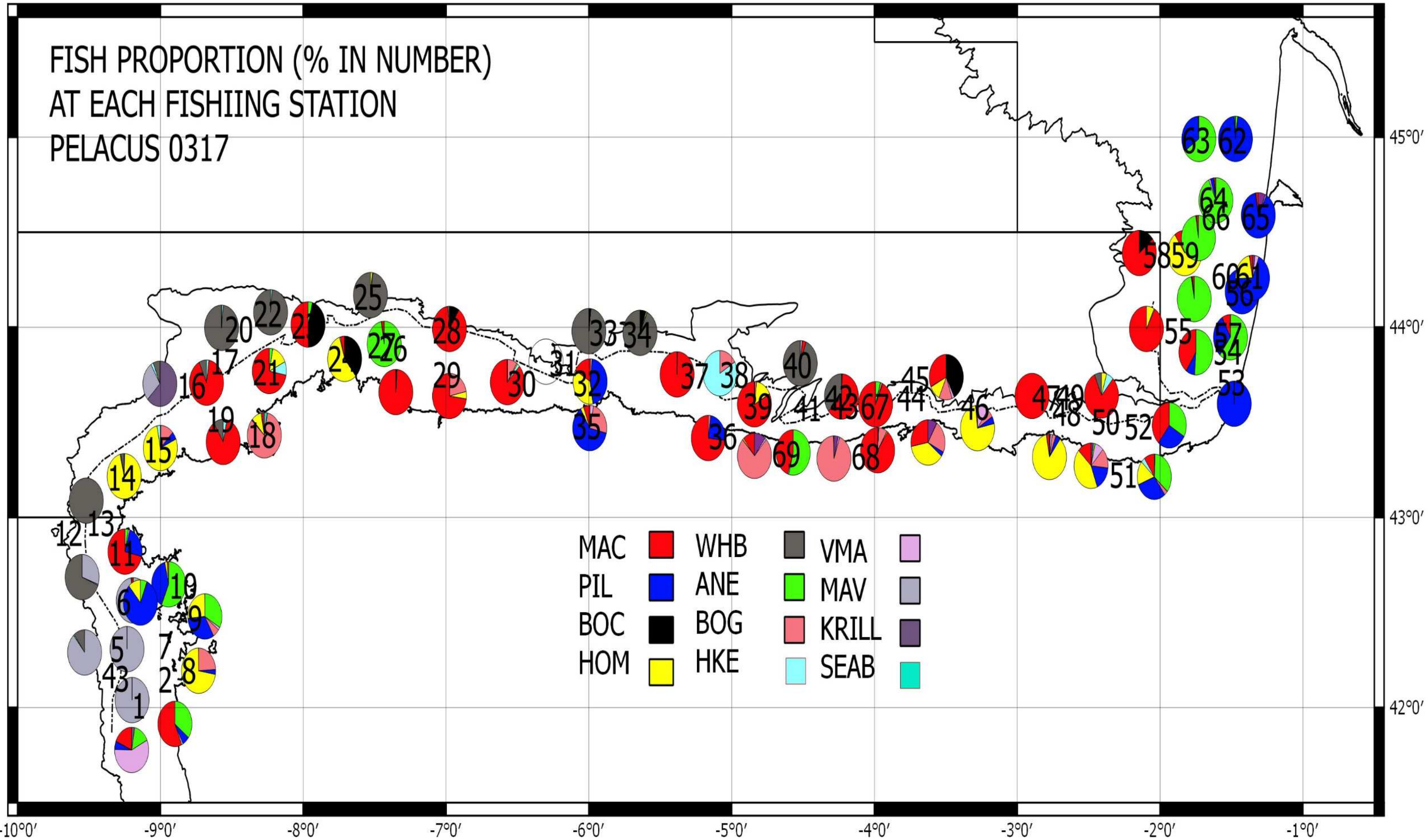


Figure 3: Fish proportion at each fishing station. (MAC-mackerel; PILsardine; BOC-boarfish; HOM- horse mackerel; WHB-blue whiting; ANE- anchovy; BOG-bogue; HKE-hake; VMA-chub mackerel; MAV-M. Muelleri KRILL -M. norvegica; SEAB- Sea breams

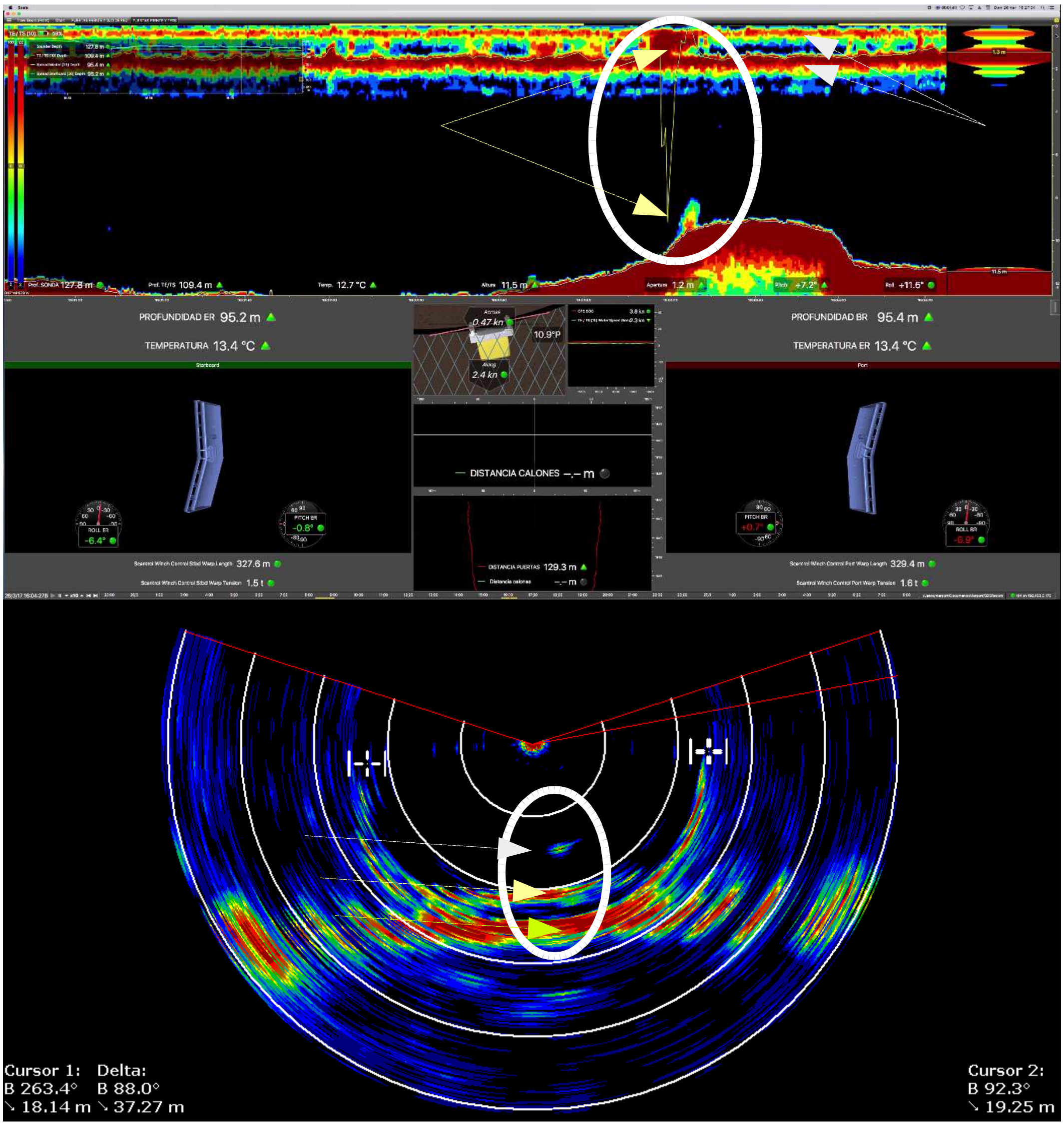


Figure 4. Screenshot from Scala software (above) and from FS70 (below). The later is showing a school being caught (encircled by the white circle, shows by a light grey arrow); the footrope (light yellow arrow) and the bottom (light green arrow), which was rough and hard, are also shown. In the former, the white circle shows the school which was partly caught (light yellow arrows are showing the caught part -upper arrow- and the escaped one -bottom arrow- close to the true bottom) together with the net opening at the codend (light grey arrows), which is around 1.5 . These devices also give parameters such as temperture depth, vertical and horizontal opening measured ate the mouth of the net, position of the door and door spread among others.

The performance of the fishing gears was good and no major problems occurred. The number of schools escaping below footrope was very low, so most of the tows but one, were considered good.

A total of 75 mt have been caught corresponding to 911 thousand specimens, 28 thousand of them being measured. Five species were present in more than a 50% of the tows (mackerel, hake, horse mackerel, sardine and chub mackerel, table 6), but mackerel represented up to 60% of the total catch in weight. On the other hand anchovy was the most important fish in number (30%), being also important (i.e. more than a 10% of the total catch in number) blue whiting, mackerel, horse mackerel and sardine.

On the other hand, as observed in the most recent years, pearlside or silvery lightfish, *Maurulicus muelleri*, was also important, specially in the southwestern area (9a). But, given the small size and also the towing speed, its representation in the catch is underestimated. This species occurs in isolate schools which shows a spatial continuity looking like a layer, located at 125 m from more or less this depth (i.e. almost starting as a bottom layer, rising from the bottom as this drops, and keeping this depth as pelagic layer until the slope, where such echotype almost change to a low dense and wide layer, located at deeper waters (200-250 m) and decreasing where other species such as blue whiting, hake or krill, *Meganictiphanes norvegica,* also occur. As for pearlside, this species, which seems to be also abundant, is understimated due to the same issues.

	TOTAL CAP (Kg)	No ind.	No Fishing st	Sample weight (kg)	Measured fish	Mean length	%PRES	% Catch_W	% Catch_No
WHB	5683	98686	23	115	1931	21.96	33.82	7.55	10.83
MAC	45085	163901	57	1720	6070	33.91	83.82	59.89	17.99
HKE	371	3162	58	220	1816	24.97	85.29	0.49	0.35
HOM	5520	140275	46	369	4238	20.16	67.65	7.33	15.40
PIL	5180	151189	36	180	3980	18.03	52.94	6.88	16.60
BOG	5259	41671	30	398	2684	24.58	44.12	6.99	4.57
VMA	1483	23640	37	239	1992	23.83	54.41	1.97	2.60
BOC	360	6235	10	54	965	14.08	14.71	0.48	0.68
SEAB	305	557	13	131	258	29.57	19.12	0.40	0.06
ANE	5638	277070	30	64	2860	14.98	44.12	7.49	30.42
HMM	393	4459	11	98	867	22.43	16.18	0.52	0.49
Total	**75275**	**910845**	**68**	**3589**	**27661**				

Table 6: Summary of the trawl haul and catches by species, indicating total catch in weight and number, the number of fishing station a particular species has been caught, the total weight and number of measured fish by specie, the overall mean length, the % of presence (number of fishing station with presence/total trawl hauls) and % in weight and number from the total catch in weight and number.

Acoustic

A total of 361.441 s_A were attributed to fish species which is higher than that of the previous year (it should be noted that this year the survey has been expanded towards 8b. Of those a 15% (54 thousand s_A) was directly allocated (table 7).

	WHB	MAC	HAK	HOM	PIL	BOG	VAM	BOC	SBR	HMM	ANE	MAV
DA	4740	9977	0	108	33399	0	0	0	253	0	2734	0
Fst	76256	5244	5370	53477	56030	68817	10429	3156	1010	4425	20162	4295
Total	80996	15222	5370	53585	89428	68817	10429	3156	1263	4425	22896	4295
% DA	5.85	65.55	0.00	0.20	37.35	0.00	0.00	0.00	20.05	0	11.94	0.00

Table 7: Backscattering energy (s_A) allocated by species, both by direct allocation (DA) and by the fish proportion (Fst) found at the ground-truth fishing stations (WHB-blue whiting; MAC-mackerel; HOM- horse mackerel; PIL-sardine; BOG-bogue; VAM-chub mackerel; BOC-boar fish; SBR-sea breams and similar specie; HMM-mediterranean horse mackerel; ANE-Anchovy; and MAV -Pearlside)

The use of multifrequency approach when scrutinizing echograms and the lack of swimbladder in relation to the other fish species made possible to directly allocate most of the back-scattering energy to mackerel (66%). This is the exception as most of the echotraces were observed in a multi-species context, thus making it difficult to directly assign these to a specific species. In this case, ground-truth fishing station are used as proxy of the species proportion. For this purposes, similarities in echotrace typologies was used as criteria to split into different strata. Within each strata, all fishing stations were used to estimate the fish proportion. No weighting factor was used, and therefore only the relative length distributions of each specie at each fishing station within the strata were used. The areas and the fishing station used are shown in table 8 and figure 5.

Area	Fishing stations	Synthetic f. st.
Continental shelf 9a	P01-P02-P11	S01
Slope 9a	P03-P04-P05-P06-P12	S02
Coastal waters 9a	P07-P08-P09-P10	S03
Slope 8c-W	P12-P13-P16-P20-P22-P25	S04
Coastal waters 8c-W	P11-P14-P15-P18	S05
Southern continental shelf 8c-W	P17-P19-P21	S06
Northern continental shelf 8c-W	P17-P19-P21-P23-P24	S07
Western coastal waters 8cEw	P26-P27-P29-P30-P32-P35	S08
Western continental shelf 8cEw	P25-P28-P33-P34	S09
Western slope 8cEw	P33-P34-P40	S10
Central coastal waters 8cEw	P32-P35-P36-P39-P41-P69	S11
Eastern coastal waters 8cEw	P43-P44-P67-P38-P69	S12
Eastern 8cEw	P42-P46	S13
Eastern slope 8cEw	P40	S14
Coastal waters near Cape Ajo	P44-P45-P46-P48	S15
Western coastal waters 8cEe	P44-P46-P48	S16
Western continental shelf 8cEe	P45-P49	S17
Western slope 8cEe	P40	S18
Central coastal waters 8cEe	P46-P48-P50	S19
Central continental shelf 8cEe	P45-P49	S20
Central slope 8cEe	P40	S21
Eastern coastal waters 8cEe	P51-P52-P53	S22
Eastern continental shelf 8cEe	P45-P49	S23
Eastern slope 8cEe	P40	S24
Coastal waters 8ab	P53-P56-P61-P62-P65	S25
Continental shelf 8ab	P54-P57-P59-P60-P63-P64-P66	S26
Slope (>130 m) 8ab	P55-P58	S27

Table 8: Strata and fishing station used for backscattering energy allocation, last column refers the name in the map of figure 5.

Fishing station 40, done at the slope has been used in eastern area as not significant changes were observed in this area. In general, fish diversity was higher in coastal waters and decreased towards deeper waters. In addition, as previously observed in Carrera (2016) and Santos et al. (2013), there is also an eastern gradient, with higher diversity in the inner part of the Bay of Biscay, thus a higher number of strata being located in this area.

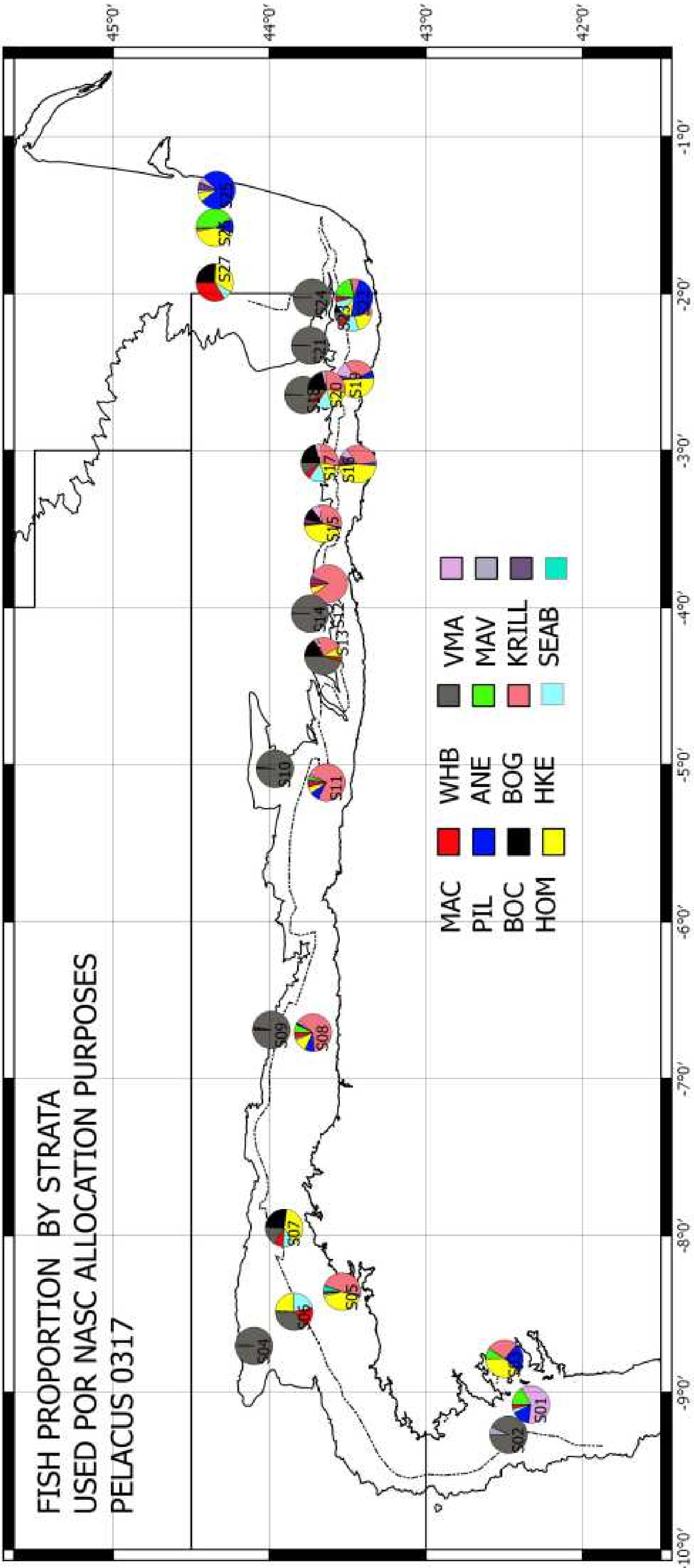


Figure 5: Fish proportion by strata used for NASC allocation proportion, according to Nakken and Dommasnes approach

Mackerel Assessment

As stated, mackerel was the most abundant fish species in biomass occurred at the fishing station. It was widely distributed all around the surveyed area (figure 6), with juveniles being located in 9a (southern part) and also in French waters (8b) and the bulk of the spawning stock biomass occurring in the Cantabrian Sea, which is in agreement with the mackerel egg records obtained with CUFES (figure 7). This situation clearly differs from that observed in 2016 when mackerel showed a highly patchy distribution, with thick schools and less in an epipelagic layer (round 20-50 m depths).

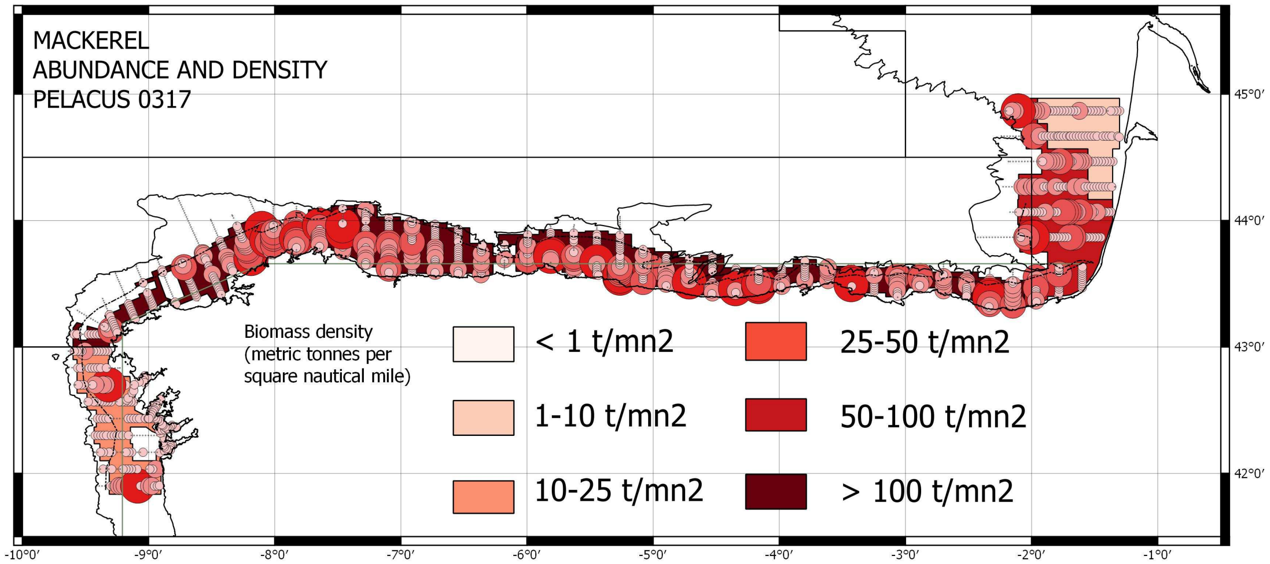


Figure 6. Mackerel spatial distribution in PELACUS0317. Polygons are drawn to encompass the observed echoes, and polygon colour indicates the mean density expressed as tonnes per squared nautical mile (<1,; 1-10; 10-25; 25-50; 50-100; and >100)

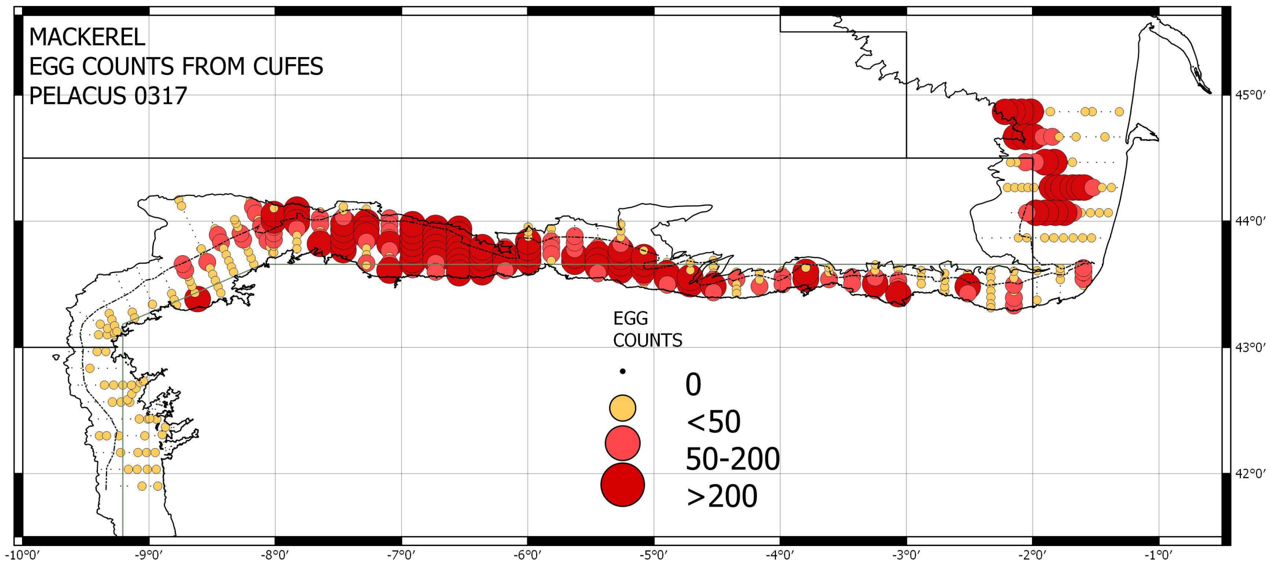


Figure 7. Mackerel egg distribution from CUFES in PELACUS0317.

Table 9, 10 and 11 show the mackerel assessment. 549 thousand tonnes, corresponding to 1778 million fish were estimated in Spanish waters, a 10% more than those estimated last year (498 thousand tonnes corresponding to 1566 million fish). Up to 80% of the fish estimated in 9a belonged to age group 1. This age group was almost negligible in 8c (only a 2%) where 90% in number had 5+ years. From north Galicia (8cW) to the inner part of the Bay of Biscay, there was no significant differences in length distribution; 23 fishing stations had no significant differences (Kolmogorov-Smirnov test) in length distribution. In the French area (south 8b), there was a small mode located at 21 cm, with the mean length being lower than that observed in the Spanish area. Nevertheless the bulk of the fish had 5+ years and age group 1 only accounted for 2% of the total abundance estimation, thus similar to the stock structure as in 8c.

		SURVEY:	PELACUS 0317 MACKEREL					
Zone	**Area**	**No**	**Mean**	**Surface**	**Fishing st.**	**PDF**	**No (million fish)**	**Biomass (tonnes)**
9a-N	9a	229	3.06	1181	P01-P02-P06-P09-P10-P11	ST01	165	14705
	Total 9a-N	***229***	***3.06***	***1181***			***165***	***14705***
8c-W	8c-W	171	16.03	1185	P29-P30-P32-P35-P36-P37-P39-P40-P41-P42-P43-P44-P45-P46-P47-P48-P49-P50-P51-P52-P67-P68-P69	ST02	360	119039
	Total	***171***	***16***	***1185***			***360***	***119039***
8c-E	8c-E	509	17.39	3913	P29-P30-P32-P35-P36-P37-P39-P40-P41-P42-P43-P44-P45-P46-P47-P48-P49-P50-P51-P52-P67-P68-P69	ST02	1253	414999
	Total	***509***	***17***	***3913***			***1253***	***414999***
	Total 8c	***680***	***17***	***5097***			***1613***	***534038***
8b	8b-S	168	14	1889	P54-P55P56-P57-P58-P59-P60-P66		480	154982
	8b-N	73	1	829	P61-P62-P63-P64-P65		37	5837
	Total 8b	***241***	***10***	***2718***			***517***	***160819***
	Total Spain	***909***	***14***	***6278***			***1778***	***548743***
	Total France	***241***	***10***	***2718***			***517***	***160819***
	Total Survey	***1150***	***13***	***8997***			***2295***	***709562***

Table 9 Mackerel acoustic assessment

Estimates by age group are shown in figure 8a-b. Age group 1 seems to be higher than in previous year, but lower than that observed in 2013 (figure 9)

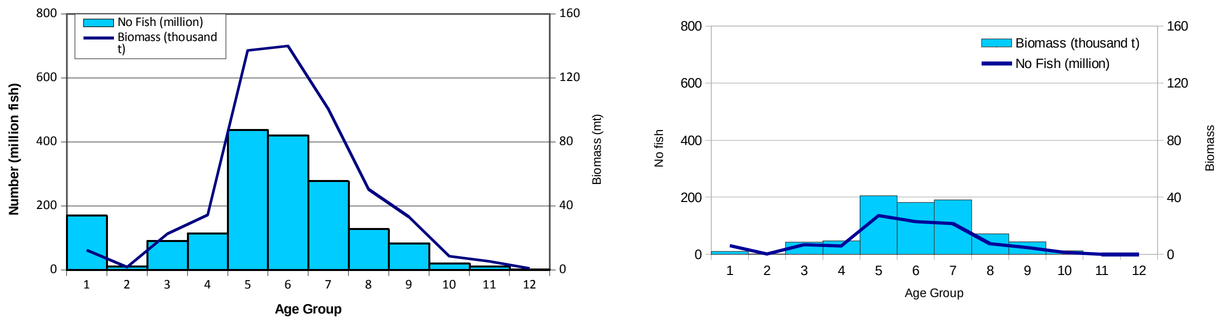


Figure 8a-b: Mackerel estimates by age group for the southern component (left panel) and south 8b (right panel)

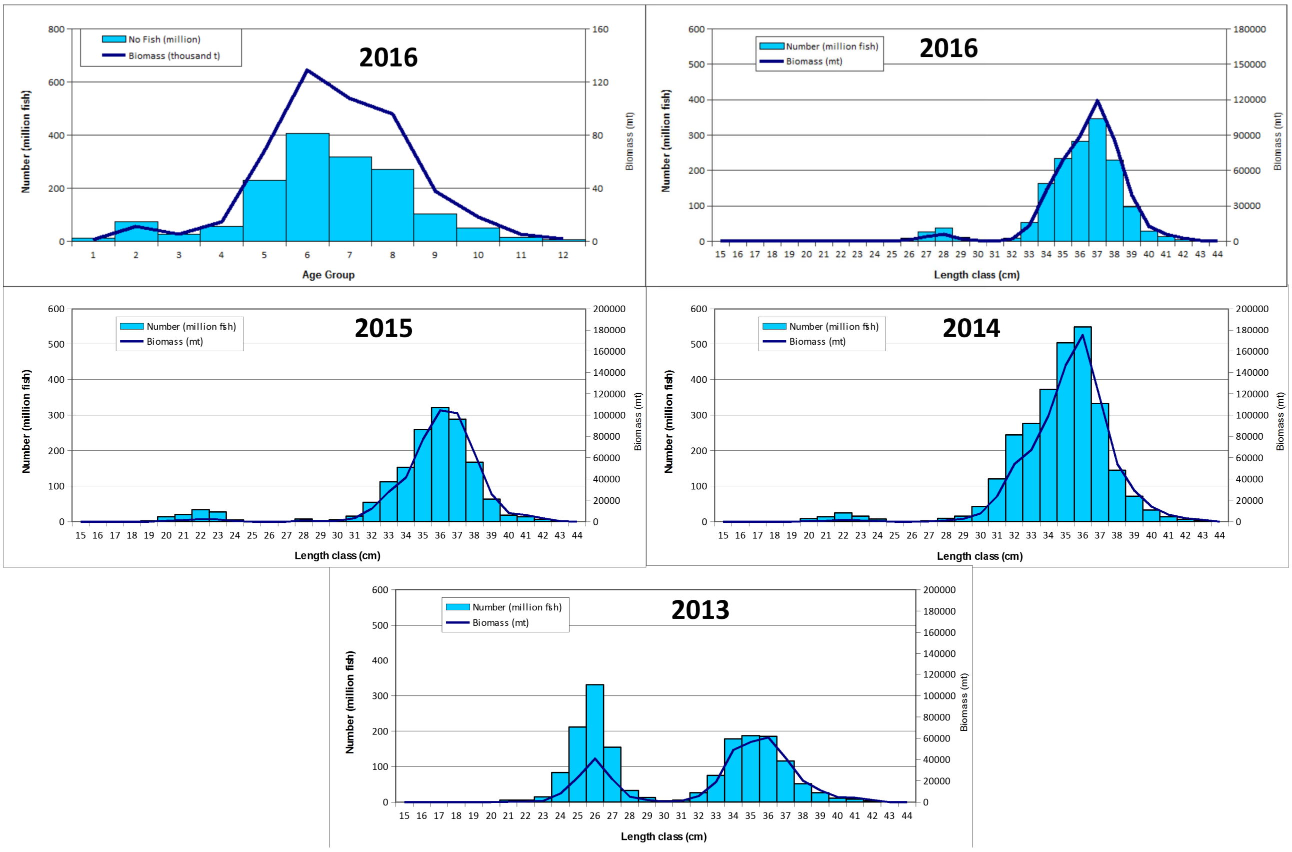


Figure 9. Mackerel age and length distribution in number and biomass estimated in 2016 together with the length distributions estimates from 2013 to 2016.

Several stock descriptors mackerel for 2013-17 time series are shown in figure 10. Mean depth has widely varied along the time series, from only 61 m in 2016, due probably to the weather conditions (see the discussion) to almost 200 m depth achieved in 2013 (i.e. range of 124 m). On the other hand, centre of gravity (CoG) along the coast did not change so much, being consistently located close to Cape Peña (figure 10a-b). In 2016, more than 70% of the fish occurred in this area. No trends in mean length nor in abundance estimates were observed (figure 10 c-d). Mean length use to be smaller in 9a than in 8c and only in 2015 were similar in both Divisions due to the increase of the fish availability in this area which would be explained by the avoidance from northwestern part (8c-W) as consequence of the strong NE winds occurred in this area (up to force 9). The lack of trends was also observed in for mean weight and biomass (figure 10e-f). Concerning abundance and biomass by age group along the time series, in 2013 there was a significant contribution of younger ages (1-2) which were not detected in the incoming years (figure 10g-h). On the contrary, in 2016, the bulk of the stock was constituted by older fish. In this case, as stated in Carrera et al. (2016), it seemed that the both the arrival and the spawning season took place later and during the survey only the biggest fish occurred, being the first to reach the spawning grounds. Both the amount of thick schools detected and also the timing of the fishery support this hypothesis. Excluding these years, no significant differences were observed in the cumulated abundance by age group. The lack of a comprehensive following of the cohorts will be further discussed. Figure 10i-n show the mean length and weight at age along the time series together with the variability for each age and year expressed as anomaly ($Mean_{year\ i}$-$Mean_{2013\text{-}17}$). No trends were observed in mean length or weight at age. Moreover, anomalies were higher in younger ages (ages 1-3) than in the older, suggesting a denso-dependence effect at younger ages.

	AGE GROUPS												
Length	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**	**No fish (million)**
10														
11														
12														
13														
14														
15														
16														
17	0.02												0.02	1
18	0.02												0.02	1
19	0.34												0.34	7
20	2.16												2.16	37
21	3.67												3.67	54
22	2.72												2.72	35
23	2.15	0.21											2.36	26
24	1.19	0.05											1.24	12
25	0.13	0.01											0.14	1
26	0.03	0.01											0.03	0
27														
28		0.67	0.13										0.80	5
29		0.84	0.54	0.41									1.79	10
30			1.32	0.90	0.90								3.13	16
31		0.10	5.93	0.57	1.31								7.92	36
32			4.24	1.17	0.74								6.16	26
33			1.92	4.46	7.37	6.47	0.74						20.96	80
34			4.86	7.24	36.29	25.19	8.18						81.76	285
35			2.95	7.00	45.41	36.22	15.30	3.84					110.71	353
36			0.74	9.87	22.03	27.13	19.47	4.28	3.25	1.25			88.02	258
37				2.88	15.58	20.23	18.71	12.58	9.81	1.24			81.04	219
38					6.42	14.86	17.96	13.08	13.85	2.99	1.55		70.71	176
39					1.16	7.82	16.52	13.02	4.06	2.32	1.16	1.16	47.22	109
40						1.61	2.68	2.81	1.07	0.94	1.35		10.45	22
41						0.39	1.17	0.48	1.17		0.30		3.52	7
42								0.15					0.15	0
43								0.13			1.06		1.19	2
44														
Biomass (thousand t)	12	2	23	35	137	140	101	50	33	9	5	1	548.23	1777
%	2.27	0.34	4.13	6.29	25.03	25.52	18.37	9.19	6.06	1.60	0.99	0.21		
M. weight	67.17	141.31	234.19	283.09	298.24	316.38	344.84	374.34	377.01	384.08	439.09	417.97	280.44	
No Fish (million)	170	12	91	116	438	421	278	129	84	22	12	3	1777	
%	9.59	0.70	5.14	6.51	24.67	23.70	15.66	7.24	4.75	1.23	0.66	0.15		
M. length	21.91	27.85	32.77	34.84	35.43	36.11	37.13	38.12	38.21	38.44	40.13	39.50	34.73	
s.d.	1.34	2.41	1.76	1.83	1.43	1.59	1.70	1.39	1.07	1.20	1.68		4.68	

Table 10: Mackerel assessment by length class and age group in 8c and 9a.

Finally figure 10-o shows the abundance estimates split in younger fish (1-3) and adults (4+). As it can be seen, the contribution of younger fish is very small, and seems, if this picture is generalised for a longer period and under a scenario of homing behaviour, that the amount of younger fish occurring in the surveyed area does not explain the big amount of older fish.

<u>Conclusion on the mackerel assessment</u>

Accounting the 2013-17 time series, mackerel population remained quite stable, both in terms of abundance, spatial distribution and age structure. Nevertheless, weather conditions (i.e. water temperature, wind strength, height of the swell among others) seem to have and important impact on the mackerel behaviour (mainly on aggregation pattern and distribution). Mackerel seems to avoid areas of high turbulence regime. Sea surface temperature and flourometry were significantly higher in 2017 than in 2016. This may explain the low egg production in relation to the available mackerel biomass observed in 2016 (figure 11). According to Hughes et al (2014) and Bruge et al (2016) the potential habitats for spawning are related with temperature, and the low temperatures achieved at the beginning of the 2016 spring would have been not suitable for spawning, shifting the peak towards end April, thus outside the survey period. This may result on an underestimation of the size of the spawning stock biomass in this area by the Egg Production Method.

Length	1	2	3	4	5	6	7	8	9	10	11	12	Total	No fish (million)
10														
11														
12														
13														
14														
15														
16	0												0.00	0
17	0												0.08	2
18	0												0.24	6
19	0												0.16	3
20	0												0.15	2
21	0												0.31	5
22	0												0.25	3
23	0												0.33	4
24	0												0.22	2
25	0												0.29	3
26	0												0.02	0
27	0	0											0.01	0
28		0											0.09	1
29		0	0										0.07	0
30			0										0.16	1
31			2										1.62	7
32			2										2.14	9
33			2		5	2							9.01	34
34			3	3	14	11	1						31.18	109
35				3	15	11	8	1	1				39.66	127
36				2	5	5	11	2	3				26.04	76
37				2	2	6	6	2	1	2			22.19	60
38							8	8					15.81	39
39						2	4		2				7.51	17
40								2	2				3.02	6
41														
42														
43														
44														
Biomass (thousand t)	2	0	8	9	41	36	38	14	9	2	0	0	161	517
%	1.28	0.08	5.27	5.86	25.54	22.60	23.72	8.86	5.33	1.45				
M. weight	61.33	155.04	238.80	307.04	288.25	302.60	338.80	371.07	360.05	355.75			287.37	
No Fish (million)	30	1	34	29	136	114	107	37	23	6	0	0	517	
%	5.80	0.15	6.52	5.66	26.27	22.12	20.77	7.10	4.39	1.22				
M. length	21.28	28.69	32.98	35.76	35.04	35.59	36.91	38.01	37.65	37.50			35.01	
s.d.	2.48	0.50	1.21	1.13	1.01	1.35	1.36	1.23	1.72				3.87	

Table 11: Mackerel assessment by length class and age group in 8b.

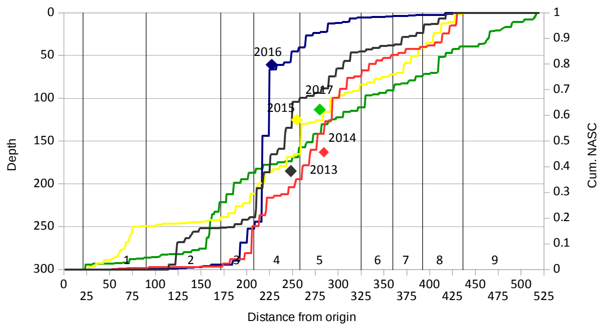
Accounting the aggregation pattern, mackerel is located either close to the bottom in thick schools or near the surface, in a continuous layer whose thickness would be driven by the weather conditions. The transition between them is quick and often a faster rising and diving reactions are observed in the echograms. In both cases, these reaction cause changes in tilt angle, and hence in the target strength, resulting in an underestimation of the backscattering energy and in the biomass. An example of such movements is shown in figure 12.

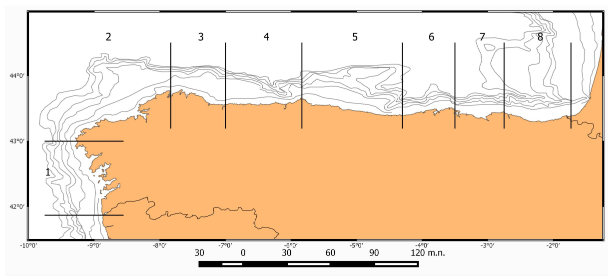
The stable age and length structure along the time series, would be also related with the southwards spawning migration. Range of the migration is length dependent and if the bulk of the southern component, rather to be exclusively located in the Cantabrian Sea also covers the Bay of Biscay the bigger fish would reach the outer part of the distribution area (e.g. Spanish waters), giving every year the same length and age structure. Moreover, the highest mean size attained in 2016 (and also the decrease in biomass) would be related with a delay in the migration, arriving at the survey time only the bigger specimens.

On the other hand juveniles are in relative terms scarce on account the spawning biomass, although annual catches of age group 1 are lower than the abundance estimated at survey time. The number of fishing station done on echotraces likely belonging to mackerel is high (hence the presence of this specie in a 84% of the trawls). Nevertheless is not usual to observe echotraces as the ones observed further north (Jansen et al. 2014) for juveniles. On account this, a possible unaccessibility of juveniles to the surveyed area and to the acoustic and trawl sampling gears

a)

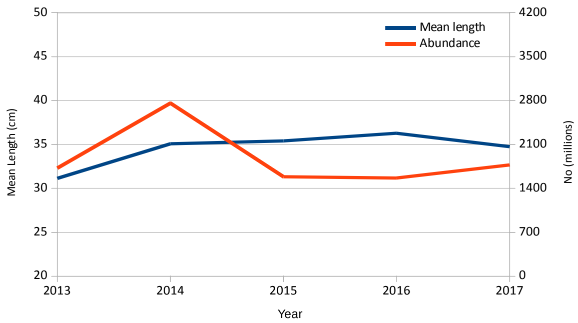
b)

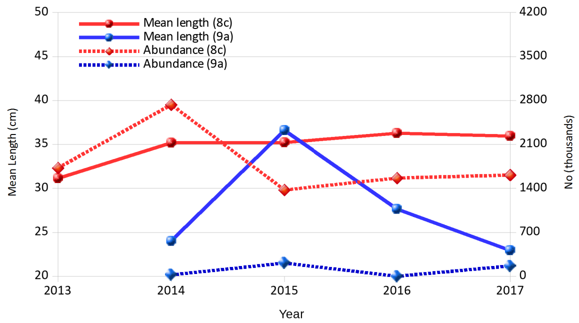

Depth
Cum. NASC
Distance from origin
2016
2017
2015
2014
2013


1
2
3
4
5
6
7
8
30 0 30 60 90 120 m.n.

c)

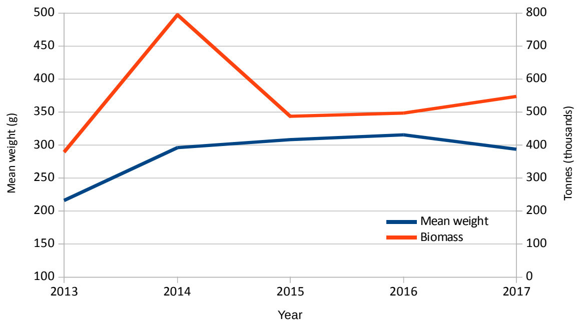
d)

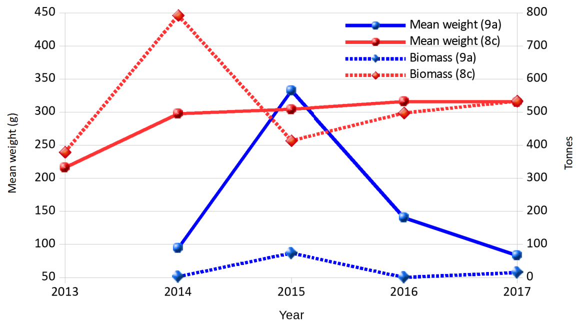

Mean length
Abundance
Mean Length (cm)
No (millions)
Year


Mean length (8c)
Mean length (9a)
Abundance (8c)
Abundance (9a)
Mean Length (cm)
No (thousands)
Year

e)

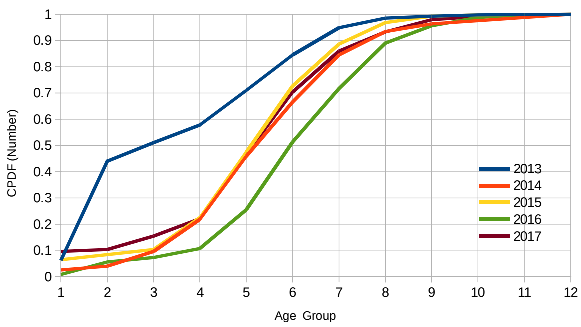
f)

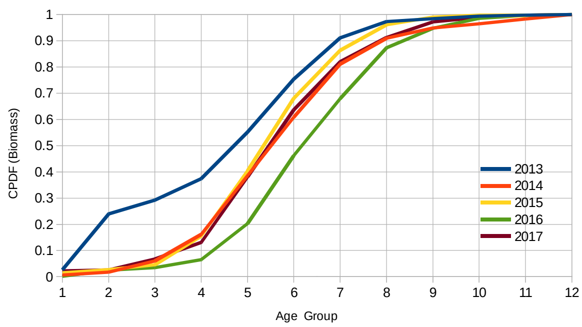

Mean weight
Biomass
Mean weight (g)
Tonnes (thousands)
Year


Mean weight (9a)
Mean weight (8c)
Biomass (9a)
Biomass (8c)
Mean weight (g)
Tonnes
Year

g)

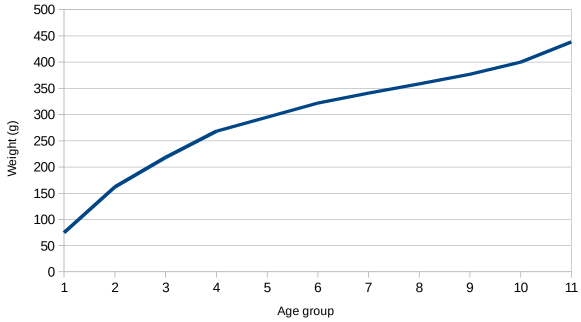
h)

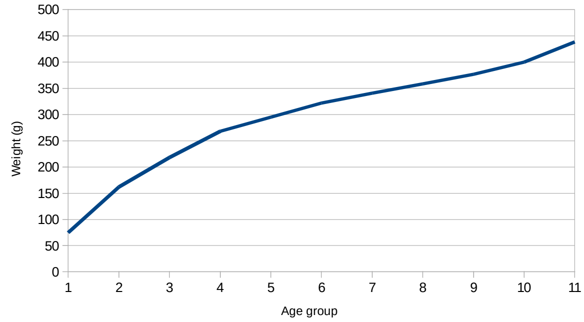

CPDF (Number)
Age Group
2013
2014
2015
2016
2017


CPDF (Biomass)
Age Group
2013
2014
2015
2016
2017

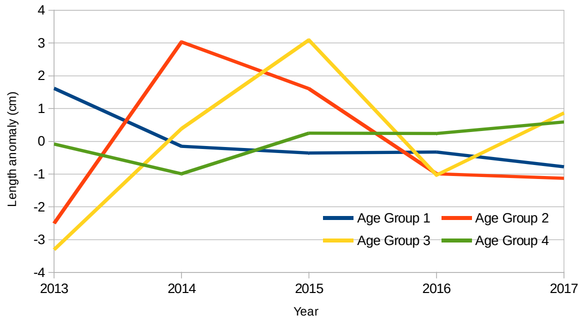
i)

j)

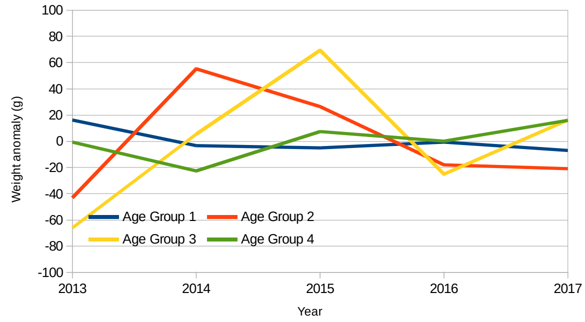




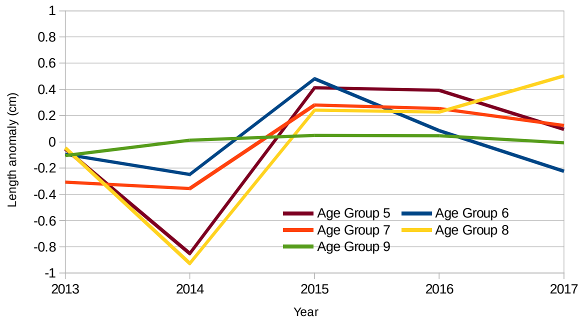
k)



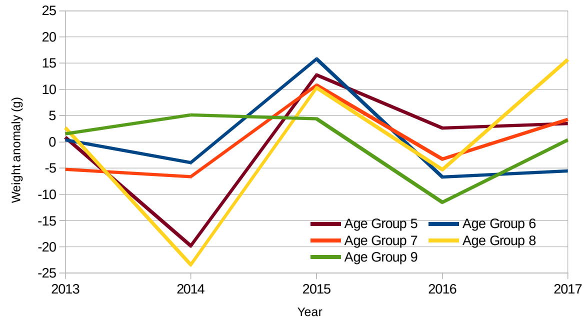
l)



m)



n)



o)

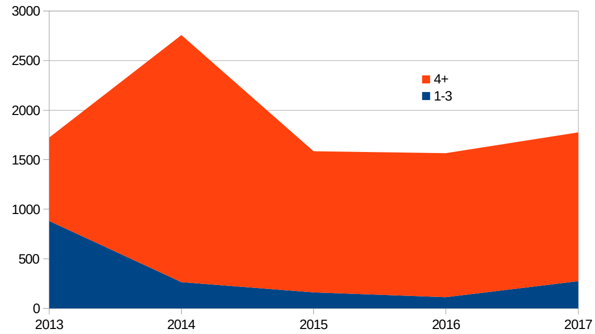


Figure 10: Mackerel stock descriptors (2013-17). a) Center of gravity along surveyed area and depth; b) map showing the number of the areas related in 10a; c) abundance and mean length estimates for the overall area; d) id by ICES Division; e) biomass and mean weight estimates for the overall area; d) id, by ICES Division; e) age cumulated abundance; f) e) age cumulated biomass; I) mean length at age; j) mean weight at age; k) length anomaly (1-4); l) weight anomaly (1-4); m) length anomaly (5-9); n) weight anomaly (5-9); and o) proportion of young (1-3) and adult fish (4+).

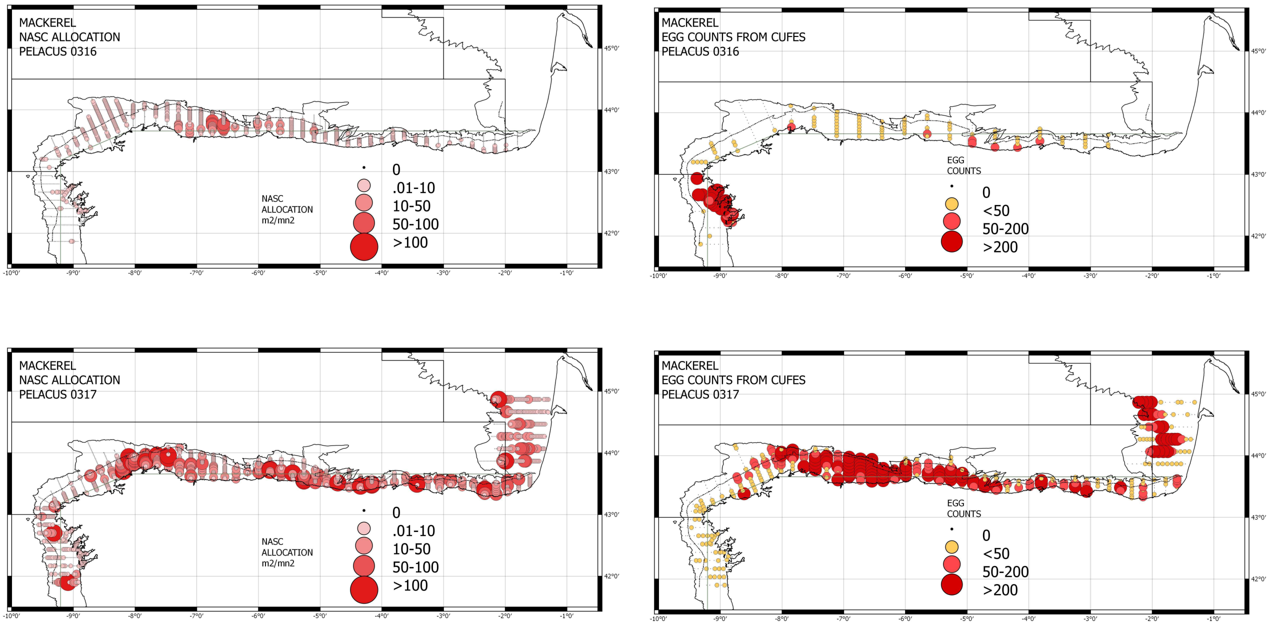


Figure 11: Mackerel s_A and egg counts distribution in PELACUS 0316 (above) and 0317 (below)

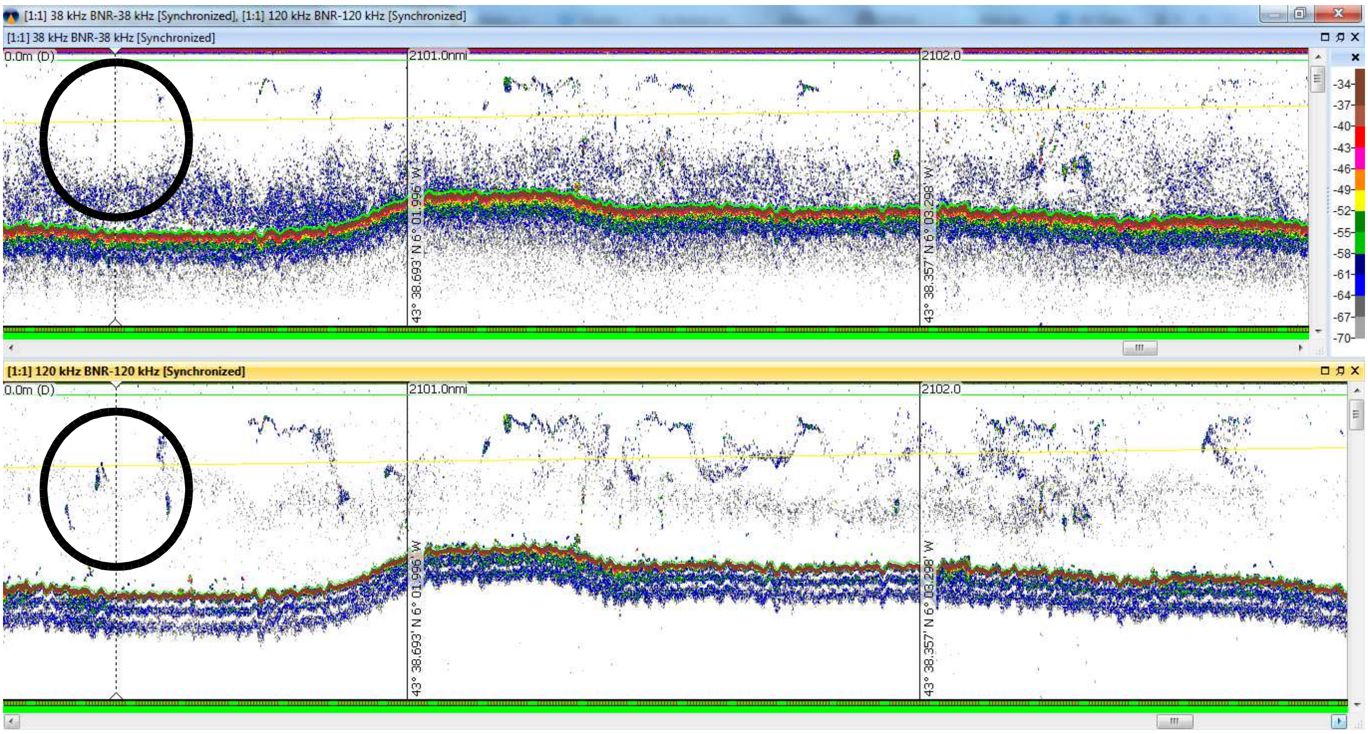


Figure 12: Echogram (38 kHz above, 120 kHz below) showing the aggregation pattern of mackerel. Below mackerel, other species (mainly bogue) were also detected. At 38 kHz, raising and diving mackerel are no detected (black circle). Threshold for both frequency is -70dB

although possible, would be negligible. Another plausible explanation is a certain unavailability, being the main nursery areas located out of northern Spanish waters. Nevertheless, a sink-source system, acting the Cantabrian Sea as a sink area, would also explain the lack of juveniles.

Blue whiting assessment

Figure 13 and table 12 shows the distribution area and the overall assessment of blue whiting. Although clearly occurrying near the slope, in the northwestern corner the distribution reaches also coastal waters. As for mackerel, length distribution was highly homogeneous along the surveyed area, with 15 fishing station, all of them located in the Cantabrian Sea and North Galicia, showing the same length distribution with mean length at 21.84 cm. In 9a, the mean length was bigger (23.01 cm)

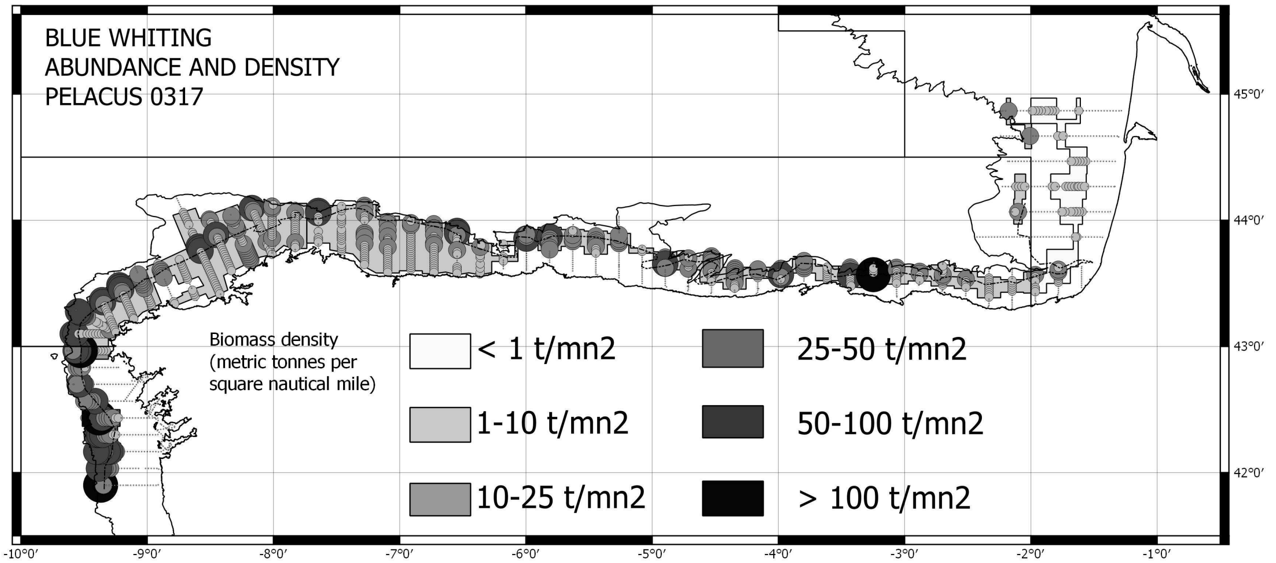


Figure 13. Blue whiting spatial distribution PELACUS0317 cruise. Polygons are drawn to encompass the allocated back-scattering energy, and polygon colour indicates the mean density expressed as tonnes per squared nautical mile (<1,; 1-10; 10-25; 25-50; 50-100; and >100)

A total of 33.71 thousand tonnes corresponding to 549 million fish has been estimated in 8c and 9a which is higher than that estimated in 2016 . In French area (8b), the abundance was very low and only 0.7 thousand tonnes, corresponding to 12 million fish were assessed.

Zone	Area	No	Mean	Area	Fishing st.	PDF	No (million fish)	Biomass (tonnes)
9a	9a_S	48	473.66	392.81	P04	S01	150	10644
	9a_N	23	451.60	157.72	P12-P13-P14-P16-P17-P19-P20-P22-P25-P28-P33-P34-P40-P42-	S02	66	3844
	Total	***71***	***467***	***551***			***216***	***14488***
8c	8c-W	281	78.36	2044	P12-P13-P14-P16-P17-P19-P20-P22-P25-P28-P33-P34-P40-P42-P49	S02	149.51	8643.89
	8c-Ew	293	69.87	2302			150.16	8681.22
	8c-Ee	67	64.83	542			32.81	1897.10
	Total	***641***	***73***	***4888***			***332***	***19222***
8b	8b_Coast	66	10.36	711	P12-P13-P14-P16-P17-P19-P20-P22-P25-P28-P33-P34-P40-P42-P49	S02	7	398
	8b_off-south	7	32.90	79			2	139
	8b_off_north	3	60.81	48			3	156
	Total	***76***	***14.43***	***837***			***12***	***693***
Total Spain		***712***	***112***	***5439***			***549***	***33710***
Total France		***76***	***14***	***837***			***12***	***693***
Total		***788***	***102.86***	***6276***			***561***	***34403***

Table 12: Blue whiting assessment

In Spanish water 43% of the abundance belonged to age group belonged to age group 2, confirming the strength of the 2015 year class. Indeed abundance of age group 3 was also greater than the 2016 cohort (figure 14 a-b and 15 and tables 13 and 14)

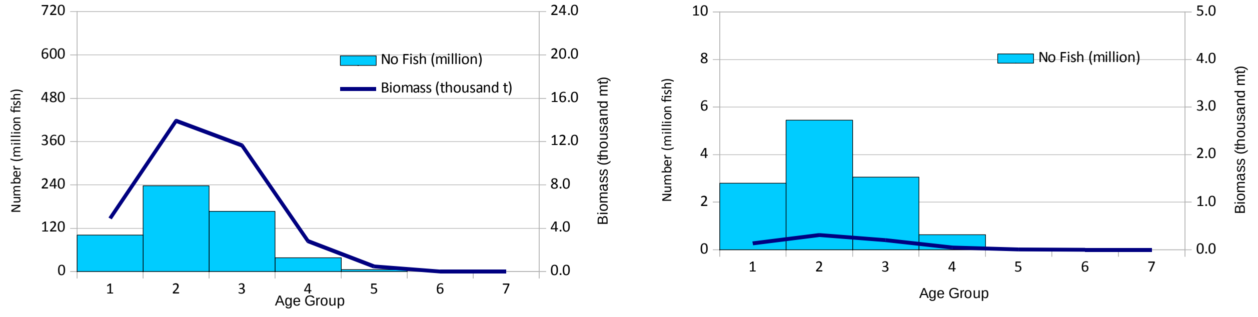


Figure 14: blue whiting assessment by age group. Left panel, 8c and 9a; right panel, 8b

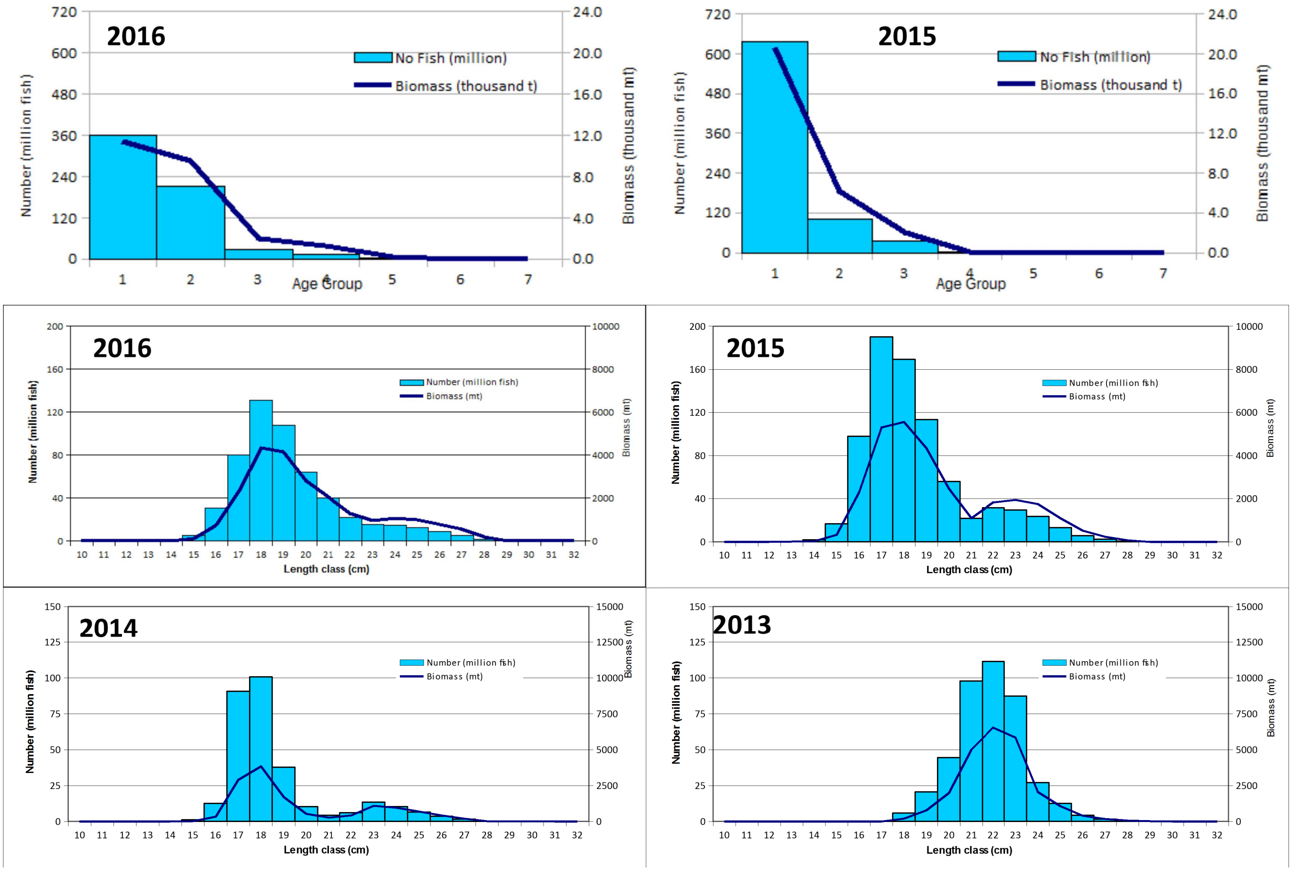


Figure 15. Blue whiting age distribution in both number and biomass during 2016 and 2015 surveys (above) and biomass and abundance estimates by length classes (2013-16 surveys).

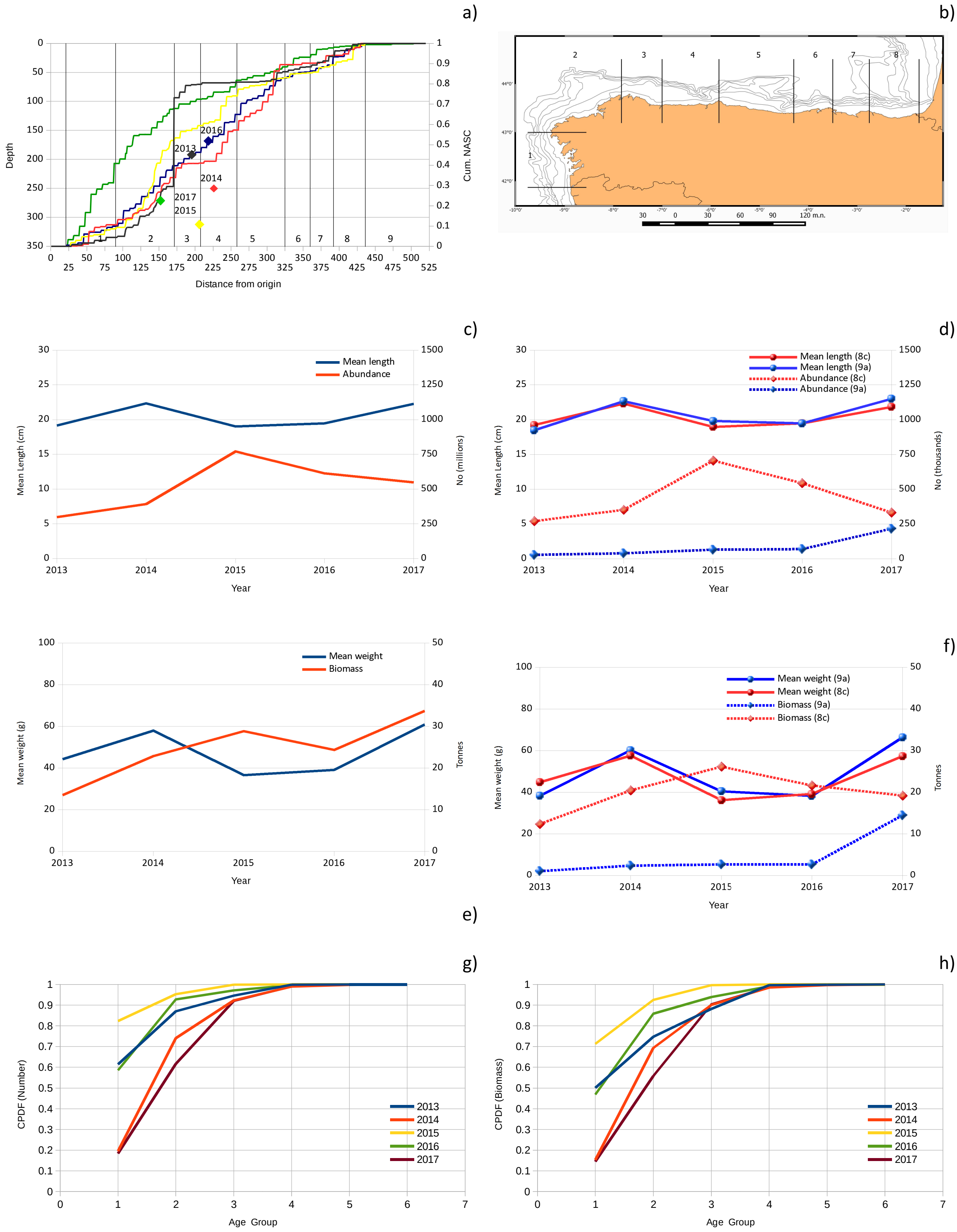
Population descriptors are shown in figure 16. Blue whiting is evenly distributed, thus with the centre of gravity being roughly located in the middle of the surveyed area (figure 16a). Mean depth is clearly located on the slope (240 m). Mean length and weight remained relative stable along the time series (2013-17), with both abundance and biomass showing an increasing trend. No significant differences in both descriptors were observed between 8c and 9a, although abundance in 9a has significantly increased this year (figure 16 c-f). Age structure is heavily dependant on the strength of the incoming year class. Age group 1 has accounted up to 70% of the total biomass (81% of the abundance), but this year is only 15% (20% in biomass), as shown in figure 16g-h. Regarding mean length and weight at age no trends have been observed along the time series (figure 16i-m). figure 16n shows the importance of younger ages (1-2) on the total abundance; althoug still important, has slightly decrease in the most recent year.

Length	1	2	3	4	5	6	7	Total	No fish (million)
10									
11									
12									
13									
14									
15									
16									
17									
18	0.11	0.07						0.18	5
19	0.82	0.66						1.48	35
20	2.33	1.62	0.30					4.25	89
21	1.31	3.81	1.43	0.36				6.90	126
22	0.33	4.25	2.61	0.22				7.40	119
23		2.22	3.01	0.95				6.17	88
24		1.12	2.25	0.64				4.01	51
25		0.18	1.07	0.18	0.36			1.79	20
26			0.20	0.20	0.10			0.51	5
27			0.24	0.24				0.49	5
28			0.46					0.46	4
29			0.03					0.03	0
30			0.03					0.03	0
Biomass (thousand t)	4.9	13.9	11.6	2.8	0.5	0.0	0.0	33.7	548.6
%	14.51	41.29	34.54	8.29	1.37			100.00	
M. weight	48.40	58.02	68.88	72.43	89.92			60.50	
No Fish (million)	101	238	167	38	5	0	0	549	
%	18.34	43.34	30.44	6.95	0.93			0.00	
M. length	20.59	21.97	23.36	23.79	25.70			22.30	
s.d.	0.87	1.33	1.64	1.60	0.40			1.76	

Table 13a: Blue whiting assessment by age class and length group in 8c and 9a.

	AGE GROUPS								
Length	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**	**No fish (milli**
10									
11									
12									
13									
14									
15									
16									
17									
18	0.00	0.00						0.01	0
19	0.02	0.02						0.04	1
20	0.07	0.05	0.01					0.12	3
21	0.03	0.10	0.04	0.01				0.17	3
22	0.01	0.09	0.05	0.00				0.16	3
23		0.04	0.05	0.02				0.11	2
24		0.01	0.03	0.01				0.05	1
25		0.00	0.01	0.00	0.00			0.02	0
26			0.00	0.00	0.00			0.01	0
27			0.00	0.00				0.00	0
28			0.00					0.00	0
29			0.00					0.00	0
30			0.00					0.00	0
Biomass (thousand t)	0.1	0.3	0.2	0.0	0.0	0.0	0.0	0.7	12.0
%	19.43	44.45	29.10	6.35	0.66			100.00	
M. weight	47.94	56.04	65.39	68.36	89.99			57.06	
No Fish (million)	3	5	3	1	0	0	0	12	
%	23.33	45.47	25.45	5.32	0.42			0.00	
M. length	20.52	21.70	22.93	23.30	25.71			21.84	
s.d.	0.84	1.27	1.51	1.45	0.41			1.58	

Table 13b: Blue whiting assessment by age class and length group in 8b.


a)
Depth
Cum. NASC
Distance from origin
2016
2013
2014
2017
2015
2
3
4
5
6
7
8
9
b)
c)
Mean length
Abundance
Mean Length (cm)
No (millions)
Year
d)
Mean length (8c)
Mean length (9a)
Abundance (8c)
Abundance (9a)
Mean Length (cm)
No (thousands)
Year
Mean weight
Biomass
Mean weight (g)
Tonnes
Year
e)
f)
Mean weight (9a)
Mean weight (8c)
Biomass (9a)
Biomass (8c)
Mean weight (g)
Tonnes
Year
g)
CPDF (Number)
Age Group
2013
2014
2015
2016
2017
h)
CPDF (Biomass)
Age Group
2013
2014
2015
2016
2017

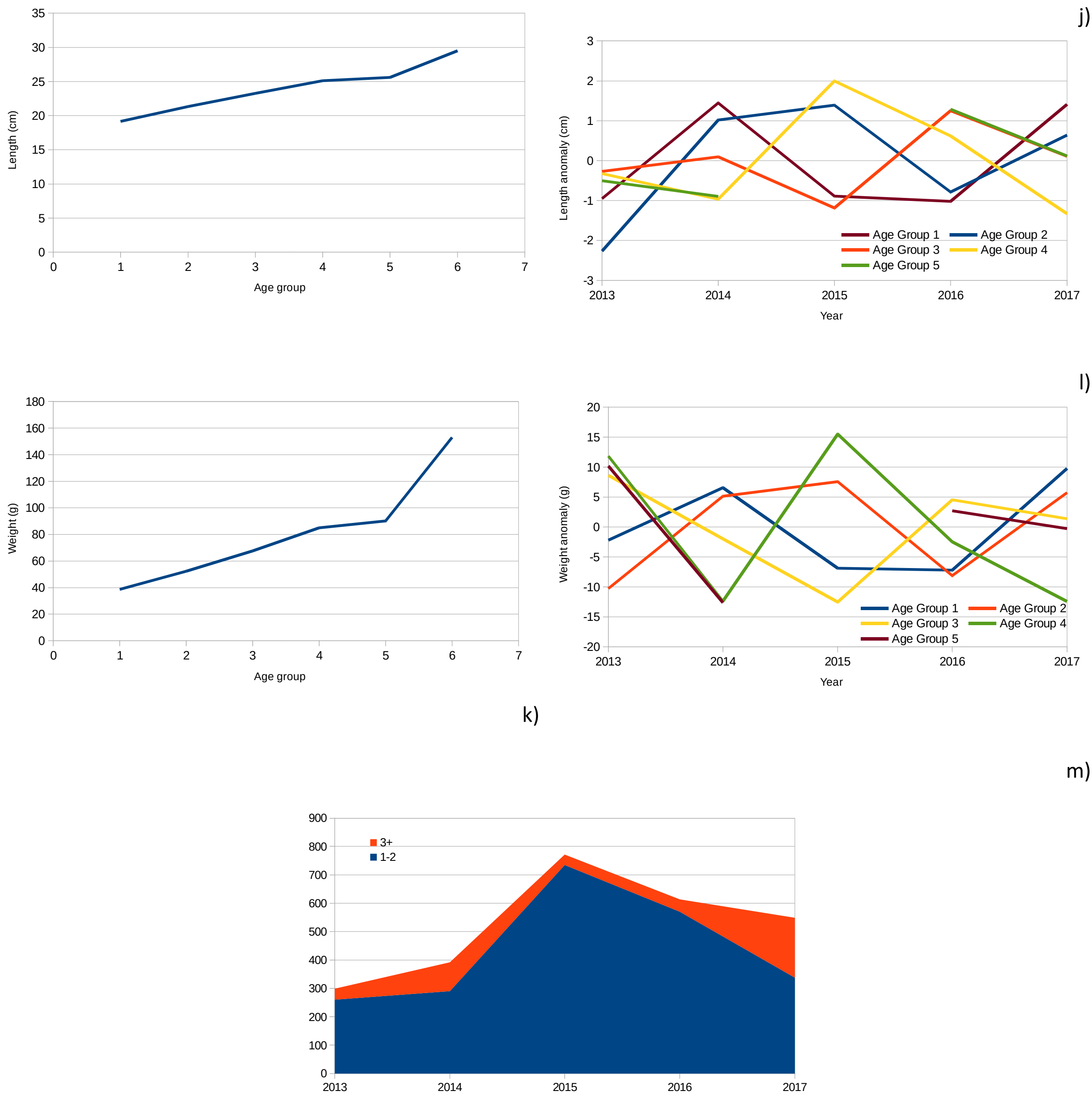


Figure 16: Blue whiting stock descriptors (2013-17). a) Centre of gravity along surveyed area and depth; b) map showing the number of the areas related in 10a; c) abundance and mean length estimates for the overall area; d) id by ICES Division; e) biomass and mean weight estimates for the overall area; d) id, by ICES Division; e) age cumulated abundance; f) age cumulated biomass; g) mean length at age; j) length anomaly; k) mean weight at age; l) weight anomaly; and m) proportion of young (1-2) and adult fish (3+).

Western horse mackerel assessment

Although figure 17 shows the horse mackerel distribution along the surveyed area and also the centre of gravity has been calculated including 9a, only the western stock (8c and 8b) assessment is described in this document.

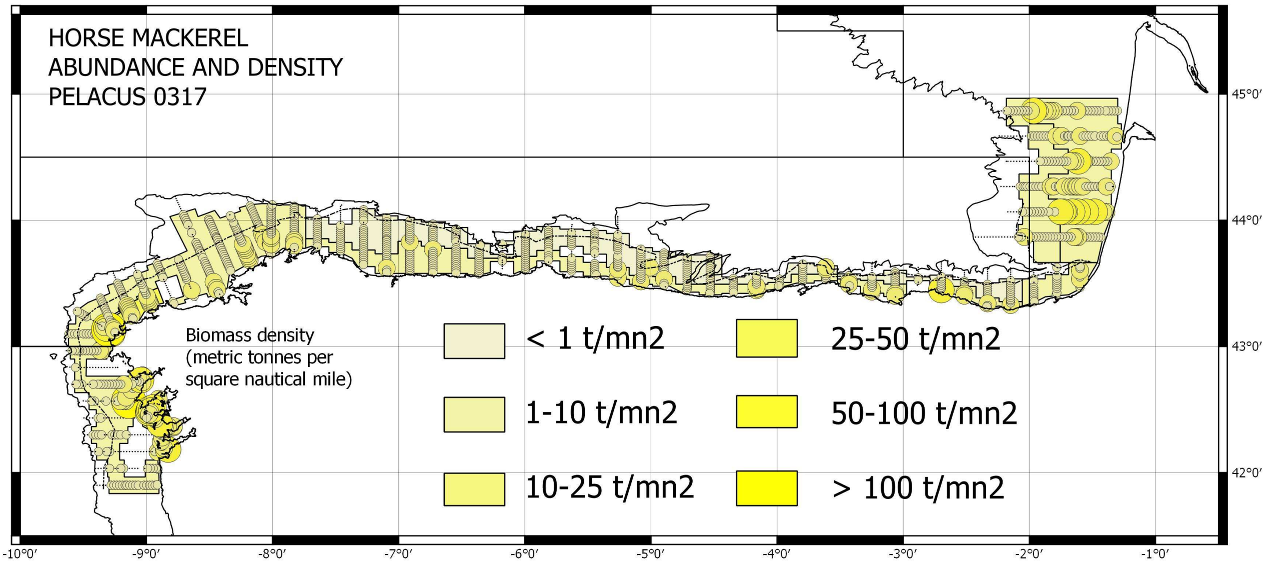


Figure 17 Horse mackerel spatial distribution PELACUS0317 cruise. Polygons are drawn to encompass the observed echoes, and polygon colour indicates the mean density expressed as tonnes per squared nautical mile (<1,; 1-10; 10-25; 25-50; 50-100; and >100

Total biomass in 8c was estimated to be 13.8 thousand tonnes (213 million fish), which is an important decrease from what has been found in the previous year. This decrease was mainly caused by the lack of younger fish (age groups 1-3, figure 17 and tables 14-15). The situation was very different from that found in south 8b. In this area, which is only a 32% of the 8c, a total of 522 million fish, corresponding to 15 thousand tonnes were assessed. The bulk of the stock belonged to age groups 1 an 2 (72.4% and 24% respectively), but the abundance of older fish (3+) was lower than that estimated in 8c. On overall, 83% of the young fish (age groups 1 and 2) were located on the French shelf (8b) while the 85% of older fish (age group 3+) occurred in 8c.

Zone	Area	No	Mean	Surface	Fishing st.	PDF	No (million fish)	Biomass (tonnes)
8c-W	8cW_COSTAMORTE	35	251.25	199.38	P14-P15	ST03	73	5120
	8cW	247	14.58	1828.66	P18-P21-P24-P25	ST04	21	3665
	Total	***282***	***44***	***2028.0***			***93.94***	***8784.75***
8c-E	8cEw_C	145	17.13	1138.91	P32-P35-P39-P44-P68-P69	ST05	43	1838
	8cEw_O	236	4.79	1841.33	P29-P30-P34-P45-P67	ST06	7	1232
	8cEe_ABRABILBAO	16	97.47	121.37	P46-P48-P50-P51	ST07	35	919
	8cEe_GIPUZKOA	19	93.04	120.62	P46-P48-P50-P51	ST07	33	872
	8cEe_O	39	4.40	311.70	P49-P55	ST08	1	199
	Total	***455***	***16***	***3534***			***118.57***	***5059.84***
8b	8b_S	34	14.53	264.35	P46-P48-P50-P51	ST07	11	298
	8b_C	132	111.15	1550.48	P56-P59-P61	ST09	505	13388
	8b_O	65	10.25	799.79	P49-P55	ST08	6	1189
	Total	***231***	***69***	***2615***			***522.38***	***14874.69***
	Total 8c	***737***	***26***	***5562***			***213***	***13845***
	Total 8b	***231***	***69***	***2615***			***522***	***14875***

Table 14: Western horse mackerel assessment

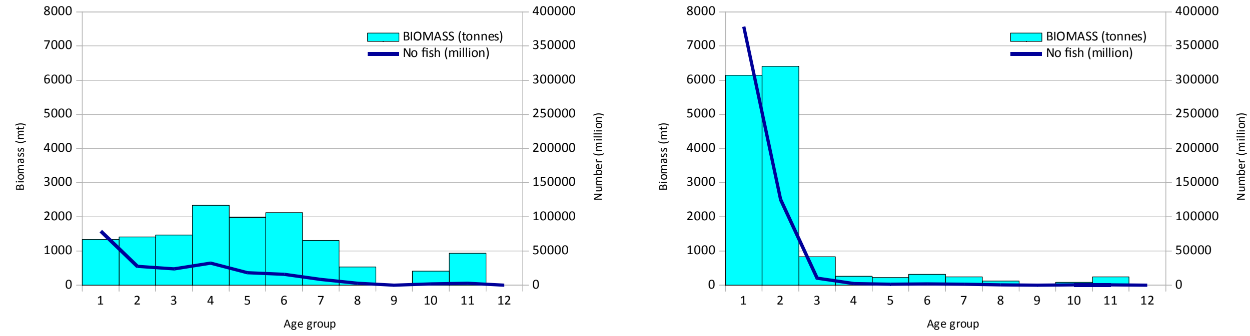


Figure 18: western stock mackerel abundance and biomass by age group. Left panel, 8c; right panel 8b.

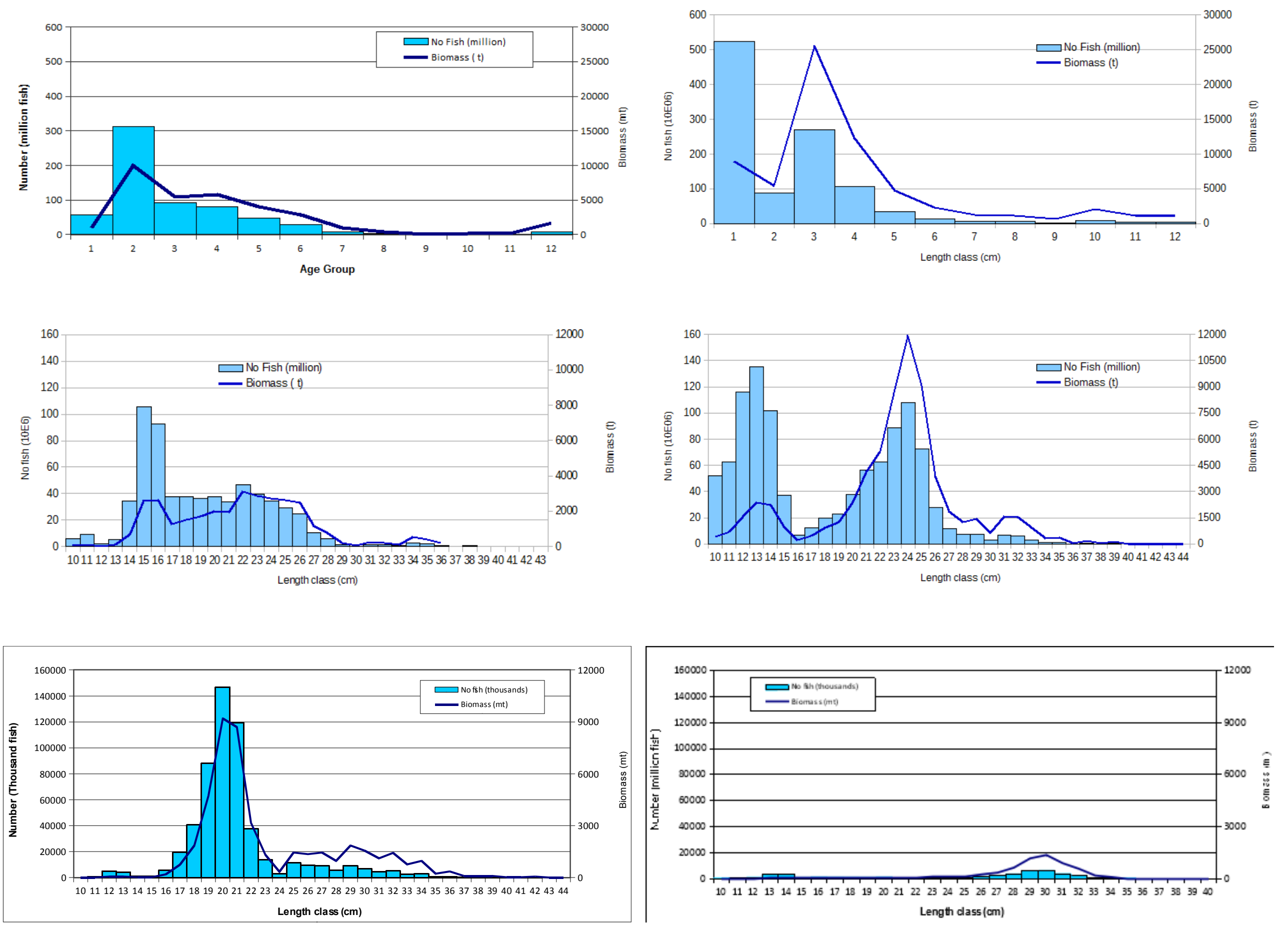


Figure 19: western stock mackerel abundance and biomass from previous surveys. Above, 2016 (left) and 2015 (right) surveys (by age group). Medium, 2016 (left) and 2015 (right) surveys (by length class). Below, 2014 (left) and 2013 (right) surveys (by length class)

Length	1	2	3	4	5	6	7	8	9	10	11	12	Total	No fish (million)
5													0	0
6													0	0
7	1												1	0
8	3												3	1
9	11												11	1
10	104												104	10
11	318												318	24
12	352												352	21
13	271												271	13
14	187												187	7
15	67	29											96	3
16	10	120	8										138	4
17	10	491	355	167									1022	22
18		397	387	580									1363	25
19		158	229	433	194								1014	16
20		127	75	265	178	21							665	9
21		72	128	83	204	115							601	7
22		10	59	28	231	301							629	7
23		4	78	117	20	301	261	20					800	7
24			95	211	95	70	279	70					819	7
25			43	275	188	22		69		23			621	5
26			14	180	443	249				47			933	6
27					401	523				29	29		982	6
28					28	423	367	28			59		904	5
29						101	402	101					603	3
30								249		83			332	1
31										136			136	1
32										92	92		184	1
33											234		234	1
34											170		170	1
35											89		89	0
36											115		115	0
37											69		69	0
38											21		21	0
39											53		53	0
40											3		3	0
Total	1333	1408	1471	2338	1981	2124	1308	536	0	410	934	0	13845	213
%	9.63	10.17	10.63	16.89	14.31	15.34	9.45	3.87		2.96	6.75		100.00	
M. weight	14.45	46.46	54.98	64.13	98.22	124.02	141.74	168.50		207.12	301.04		46.36	
No Fish ('000)	78879	27490	23963	32296	18075	15638	8486	2936	0	1844	2903	0	212509	
%	37.12	12.94	11.28	15.20	8.51	7.36	3.99	1.38		0.87	1.37		0.00	
M. length	12.30	18.12	19.16	20.16	23.23	25.10	26.23	27.78		29.75	33.68		18.10	
s.d.	1.41	1.31	2.01	2.55	2.93	2.63	2.54	2.70		2.48	2.97		5.63	

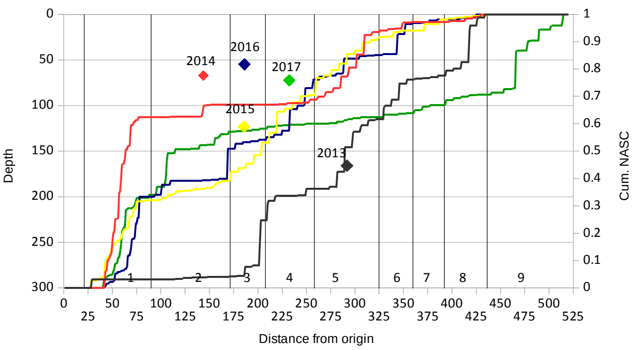
Table 15a: Western horse mackerel abundance and biomass by age group and length class in 8c

Figure 19 shows the horse mackerel population descriptors for the period 2013-17. The centre of gravity was highly variable. Except in 2013, more than 30% was located in 9a (south Fisterra cap, area 1, figure 19a). In 8c, the central part of the Bay of Biscay seems to be the main area. Depth varied between 60 to 160 m, although the distribution use to be bimodal, with a peak located in shallower waters, mainly with small size specimen, and the other close to the slope, where fish are bigger. Nevertheless, sometimes some schools of very small horse mackerel were also observed in this area. Highest abundance was reached in 2015 when horse mackerel was evenly distributed all around the surveyed area. Since that, there is a decreasing trend. Also mean length shows a decreasing trend, which is less evident in mean weight (figure 19c-d). Cumulated age distribution in number and weight along the time series is shown in figure 19e-f. Juveniles (age groups 1-2) accounts for 50% of the population in number, except in 2013. Older fish has a little contribution (a 15%, excluding again 2013). In weight 60% of fish had 5 years or less, but in 2013 this groups accounted only the 20% of the biomass. Mean length at age show a clear decreasing trend in all ages (1-8). In weight this decreasing trend is clear for ages 2-8 until 2016. In 2017, although mean length is smaller than that estimated in 2016, mean weight at age is higher (figure 19g-l). The contribution to total abundance of younger fish was the lowest in 2013, when only accounted for the 35%, reaching up to 75% next year due to the significant increase in availability of age group 2, and being stable in 2015-16, the former year due to the strength of the 2014 cohort at age 1 with 523 million fish, and the later when this cohort had 2 years with 313 million fish. In 2017,, the percentage decrease a little (50%), This percentage is too low because the strength of 2015 and 2016 year classes seems to lower than that of 2014. On the contrary, the contribution of the 2014 cohort to the abundance in 2017 was surprisingly low, as only 24 million fish were estiamted.

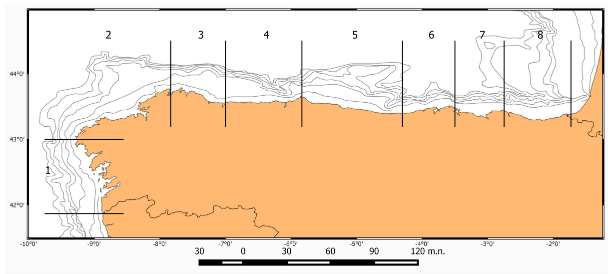
Length	1	2	3	4	5	6	7	8	9	10	11	12	Total	No fish (million)
5													0	0
6													0	0
7													0	0
8													0	0
9													0	0
10	752												752	73
11	1826												1826	136
12	1299												1299	76
13	1147												1147	54
14	795												795	30
15	237	104											341	11
16	45	518											563	15
17	49	2140											2188	48
18		2059											2059	38
19		752	167										919	15
20		651	175	25									851	12
21		153	260										413	5
22		30	169	79									278	3
23		2	44	66									112	1
24			3	6	3								12	0
25			5	33	23	3							64	0
26			4	50	123	69							247	2
27					61	79							140	1
28					10	143	124	10					286	1
29						28	114	28					171	1
30								83		28			111	0
31										38			38	0
32										19	19		38	0
33											25		25	0
34											16		16	0
35											29		29	0
36											47		47	0
37											27		27	0
38											37		37	0
39											26		26	0
40											19		19	0
Total	6151	6407	827	260	219	323	238	121	0	85	244	0	14875	522
%	41.35	43.08	5.56	1.75	1.47	2.17	1.60	0.81		0.57	1.64		100.00	
M. weight	13.92	46.53	72.90	99.79	149.02	168.65	190.80	213.76		242.31	374.96		21.35	
No Fish ('000)	378389	125259	10460	2402	1388	1808	1183	539	0	333	617	0	522378	
%	72.44	23.98	2.00	0.46	0.27	0.35	0.23	0.10		0.06	0.12		0.00	
M. length	12.14	18.13	21.04	23.35	26.67	27.79	28.95	30.07		31.34	36.23		14.00	
s.d.	1.33	1.21	1.22	1.80	0.74	0.96	0.50	0.66		0.73	2.35		3.51	

Table 15b: Western horse mackerel abundance and biomass by age group and length class in 8b

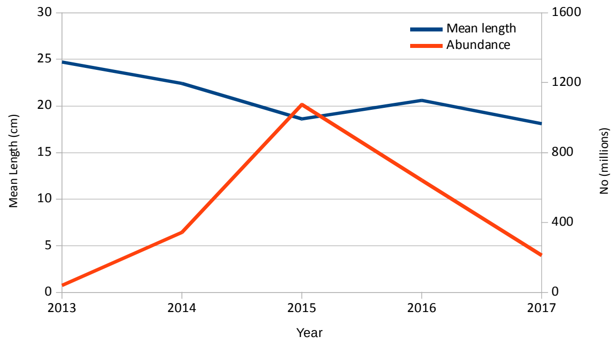
a)


Depth
Cum. NASC
Distance from origin
2013
2014
2015
2016
2017

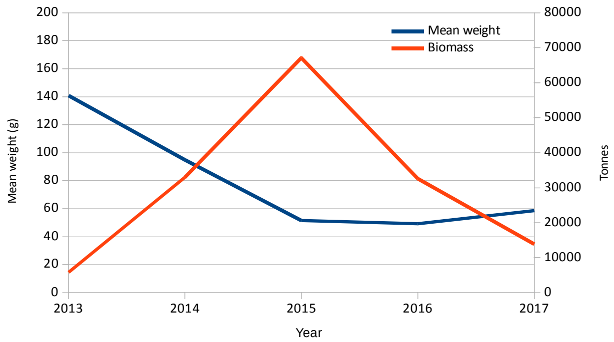
b)


120 m.n.

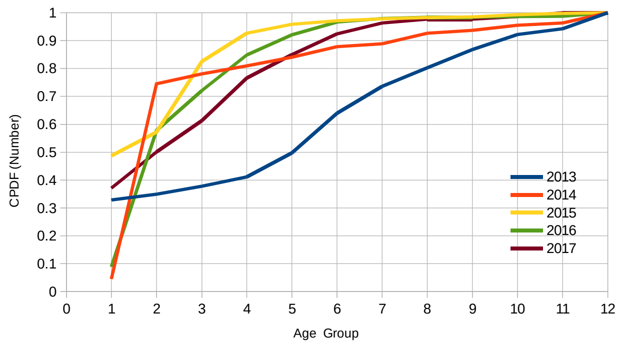
c)


Mean length
Abundance
Mean Length (cm)
No (millions)
Year

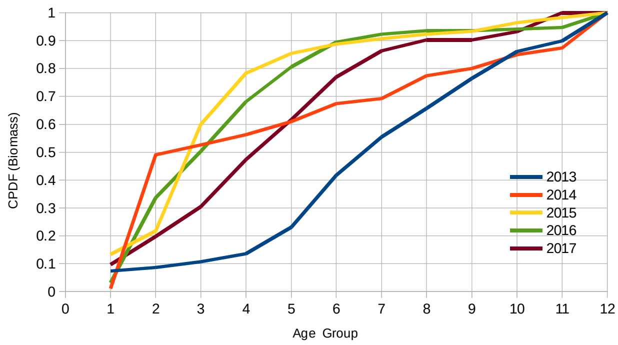
d)


Mean weight
Biomass
Mean weight (g)
Tonnes
Year

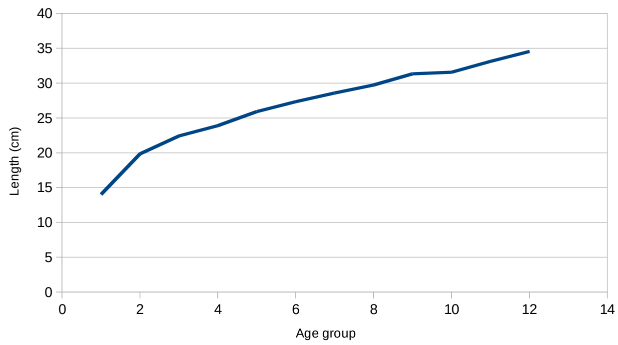
e)


CPDF (Number)
Age Group
2013
2014
2015
2016
2017

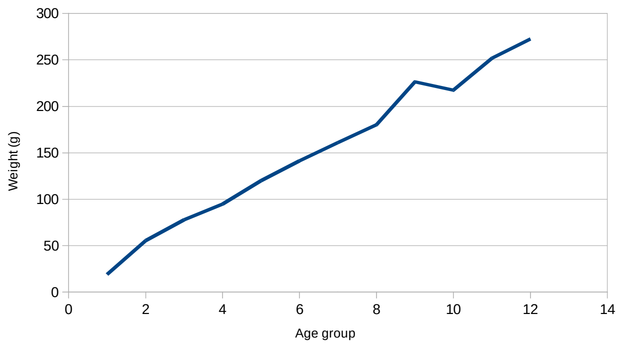
f)

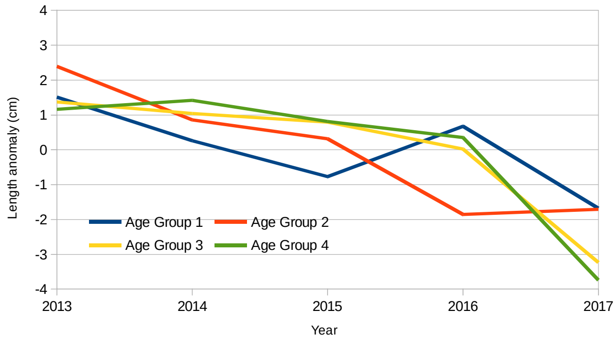

CPDF (Biomass)
Age Group
2013
2014
2015
2016
2017

g)

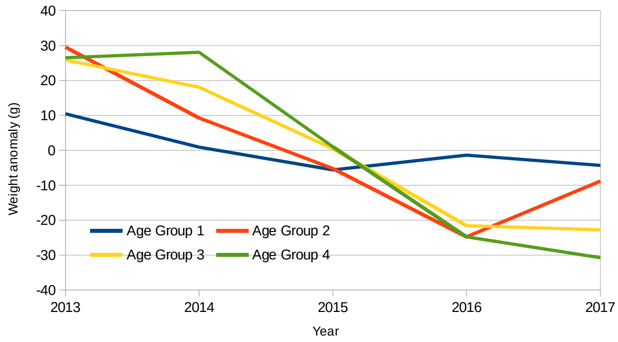

Length (cm)
Age group

h)

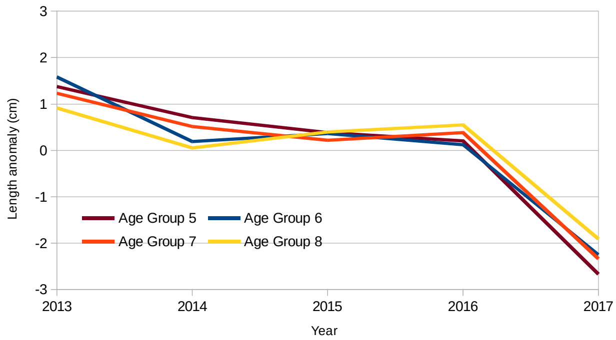

Weight (g)
Age group



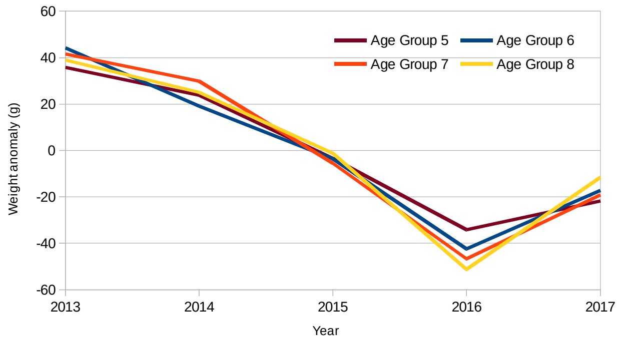
j)



k)



l)



n)

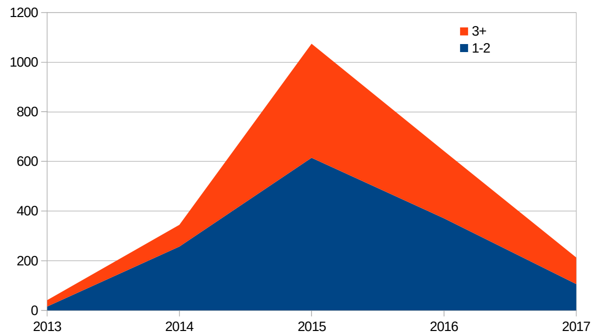


Figure 19: Western horse mackerel stock descriptors (2013-17). a) Center of gravity along surveyed area and depth; b) map showing the number of the areas related in 10a; c) annual abundance and mean length estimates; d) annual biomass and mean weight estimates for the overall area; e) age cumulated abundance; f) age cumulated biomass; g) mean length at age; h) mean weight at age; i) length anomaly (1-4); j) weight anomaly (1-4); k) length anomaly (5-8); l) weight anomaly (5-8); and m) proportion of young (1-2) and adult fish (3+).

Conclusion on the horse mackerel assessment

As stated in Abaunza (2008), the dynamics of horse mackerel is poorly understood. Once the fish are mature, at length 20-25, its availability to fishing grounds and survey area decrease, increasing again when fish reach 30 cm. This phenomena seems to occur in the Cantabrian sea. 2014 cohort, which was fully available in 2015 and 2016, almost disappeared in 2017. This phenomena together with the different strength of the year classes could explain the great changes in abundance and biomass.

Although growth tends to be isometric, denso-depence growth was also observed in this species (Abaunza et al., 2003). In 2016, the parameter b of the length weight relationship was significantly lower than those observed in the rest of the time series (only 2.764), this low value together with the almost isometric estimated in 2017 (b=3.01424) explains that most of the mean weight at age increased from 2016 to 2017 while the mean length showed opposite trend.

The extension of the survey towards 8b, has revealed the predominance of this area as nursery for this specie. The phenomena occurs for anchovy. Although the pre-juveniles occurs overall the Bay of Biscay and mainly off-shore the Spanish coast, the recruitment at age 1 is located in French area (Boyra et al., 2013). In spite the shortness of this observation (only one year), the prevalence of the French shelf as nursery could be general for other species. Further studies will be needed in order to confirm this prevalence.

Boarfish assessment

Comparing to 2016, the spatial distribution of boarfish in 2017 was higher, although, the major density was located, as in previous year, in the northwestern conner of the Iberian peninsula (figure 20). Again only schools were clearly detected in this area while in the rest, boarfish occurred in thin layers, close to the bottom, and seemed to be associated with other fish species. The distribution, although not as much widely as that of blue whiting, resembles it. In the northwestern corner, the distribution spreads out towards shallower waters while in the eastern part almost occur close to the slope. And, as in previous years, no fish was detected in 9a.

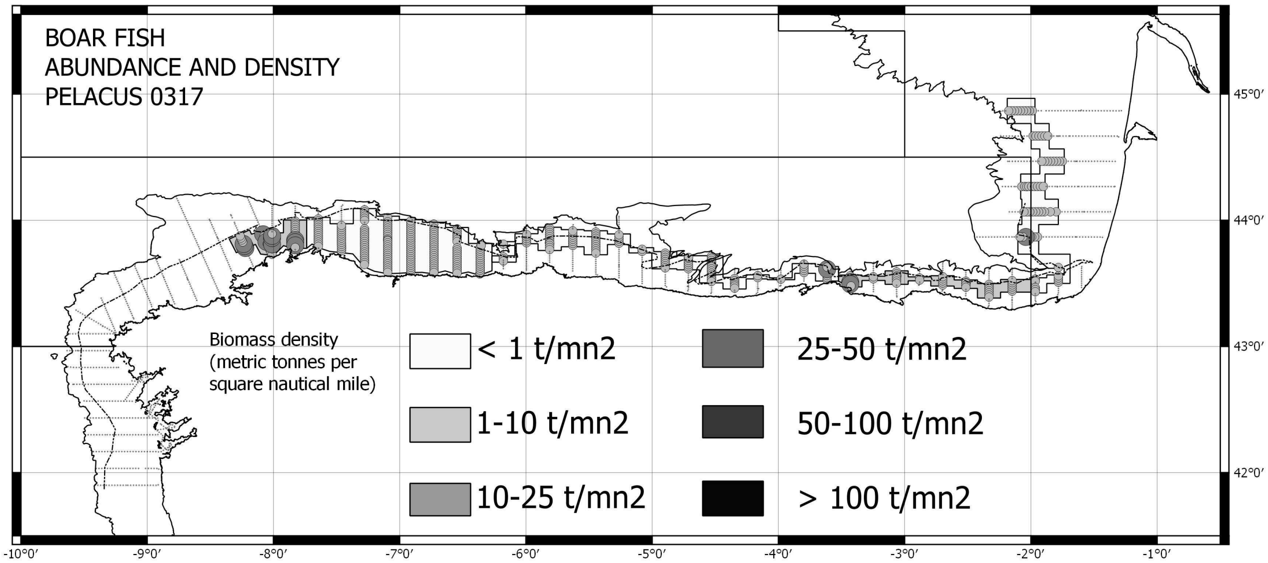


Figure 20. Boar fish spatial distribution PELACUS0317 cruise. Polygons are drawn to encompass the observed echoes, and polygon colour indicates the mean density expressed as tonnes per squared nautical mile (<1,; 1-10; 10-25; 25-50; 50-100; and >100)

Table 16 shows the boar fish assessment. In 2017 abundance and biomass were slightly higher than that estimated in 2016, the lowest of the time series. 1803 tonnes corresponding to 32 millions fish were estimated in 8c, and 486, corresponding to 9 millions fish, were in 8b. As can bi see, the lack of full length structure in 8b was an issue, but on account the few exemplars caught in the inner part, the length distribution was similar to that found in the western part, being, therefore, used the fishing station number 21 as a proxy.

Zone	Area	No	Mean	Area	Fishing st.	PDF	No (million fish)	Biomass (tonnes)
8cW	8cW	44	35.88	257.44	P21	S01	14.14	877.39
	Total	***44***	***36***	***257***			***14***	***877***
8cE	8cEw(w)	170	1.44	1332.21	P24	S02	3	174
	8cEw(e)	97	4.41	770.78	P27	S03	6	309
	8cEe	40	15.51	313.68	P28	S04	9	442
	Total	***307***	***4.21***	***2417***			***18***	***926***
Total 8c		***351***	***8***	***2674***			***32***	***1803***
8b	8b	64	6.81	785.56	P21	S01	9.39	486.36
Total Spain		***351***	***8***	***2674***			***32***	***1803***
Total France		***64***	***7***	***786***			***9***	***486***
Total Area		***415***	***8***	***3460***			***41***	***2289***

Table 16. Boar fish assesment

Figure 21 shows the abundance and biomass by length estimated in 2017. Only a mode, located at 14 cm was found. This is rather similar to those found in 2016 and 2015, but comparing with those of 2013 and 2014, there isn't a second mode, located at 8 cm. Therefore, since 2014 no strong year classes were detected, which could explain the decreasing trend (figure 22).

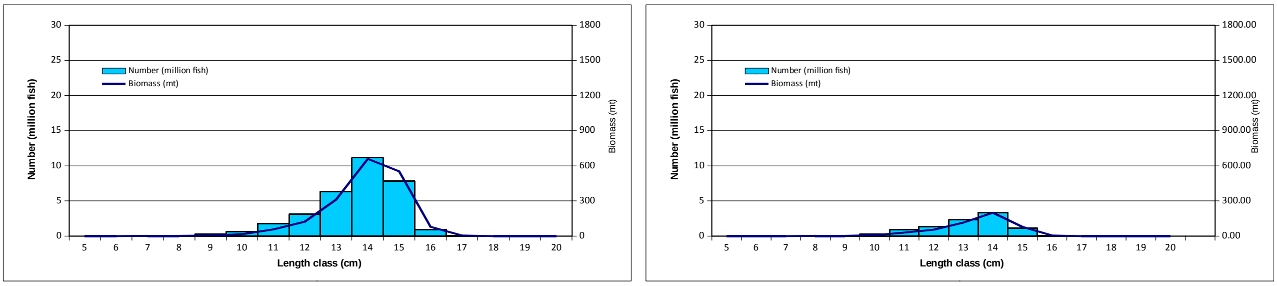


Figure 21. Boar fish length distribution in both number and biomass during the PELACUS0317. Left panel 8c, right panel 8b

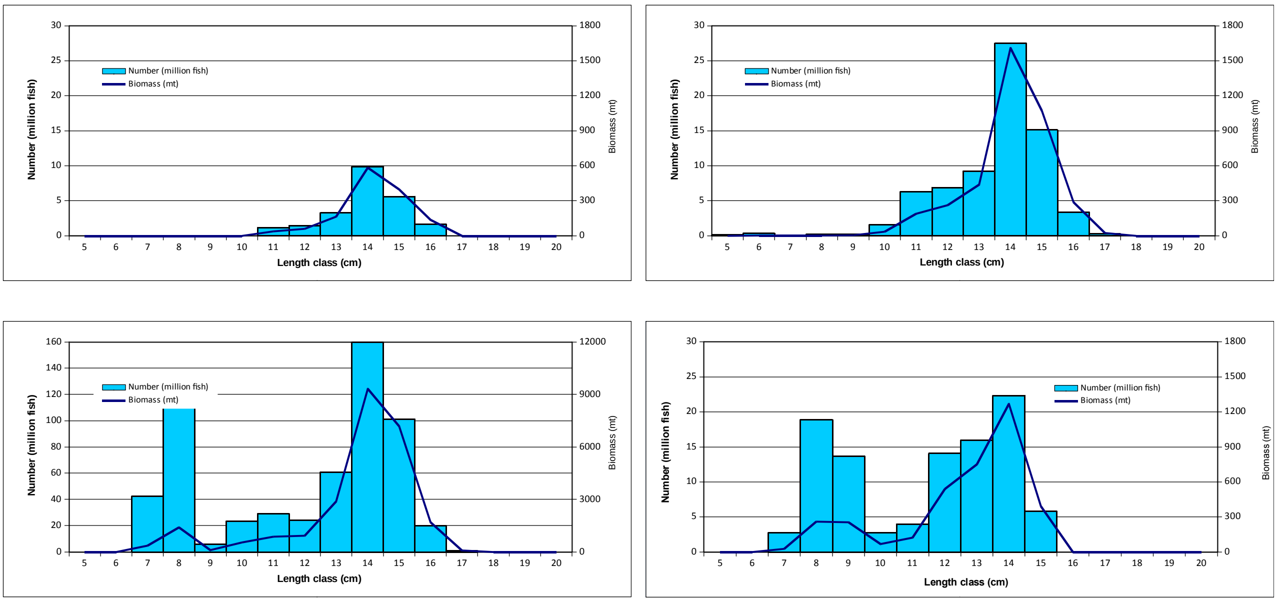
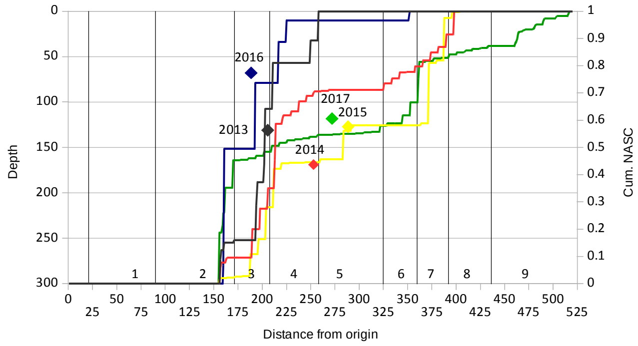


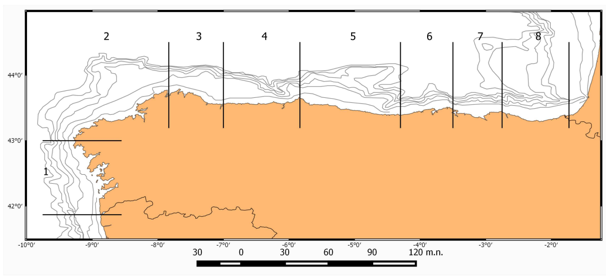
Figure 22. Boarfish length distribution in both number and biomass. Above, left panel, PELACUS 0316, right PELACUS 0315, below, left panel PELACUS 0314; right panel PELACUS 0313 All plots have the same scale except that of 2014.

Figure 23 shows several stock descriptors. Centre of gravity is very constant, with almost 50% of the cumulated energy located at the confluence of the Atlantic Ocean and the Cantabrian Sea. In the same way, mean depth is also stable (figure 23a-b). Giving the lack of incoming younger fish, both mean length and weight show an increasing trend since 2013. Abundance and biomass, after the highest value achieved in 2014, shows a slight decreasing trend (figure 23c-d). Trends in mean length and weight are much clearer in figure 23e-f, occurring the main change from 2015 to 2016. Cumulated abundance and biomass by length class is shown in figure 23g-h, which are in agreement with the previous ones, with a significant change occurred in 2015. Figure 23i, reflects the contribution of both modes (8 cm and 14 cm) to the abundance. Since 2015 the contribution of the smaller fish is negligible.

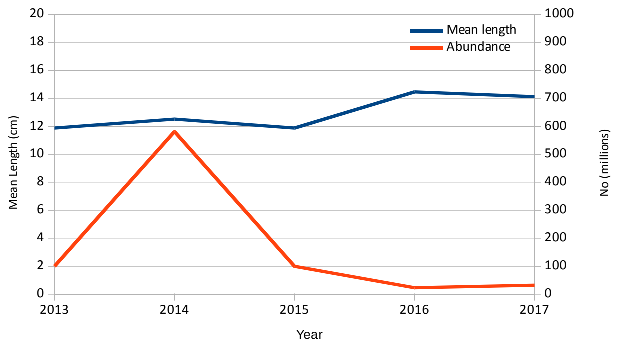
a)


Depth
Cum. NASC
Distance from origin
2016
2017
2015
2013
2014
1
2
3
4
5
6
7
8
9

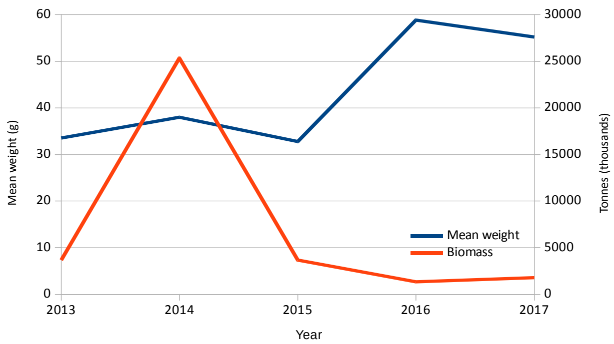
b)


120 m.n.

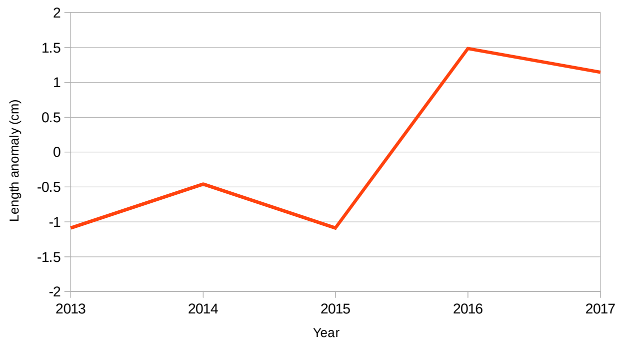
c)


Mean length
Abundance
Mean Length (cm)
No (millions)
Year

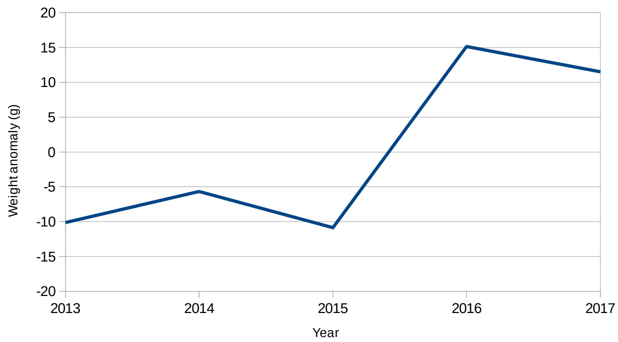
d)


Mean weight
Biomass
Mean weight (g)
Tonnes (thousands)
Year

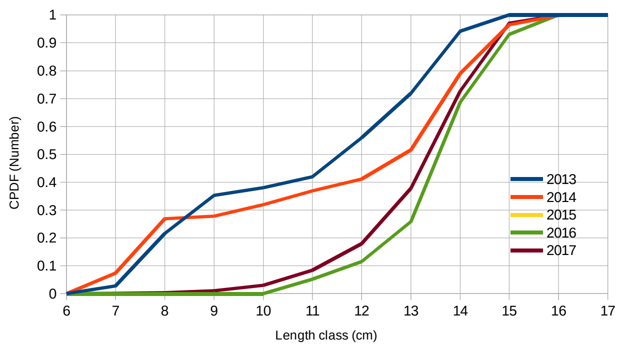
e)


Length anomaly (cm)
Year

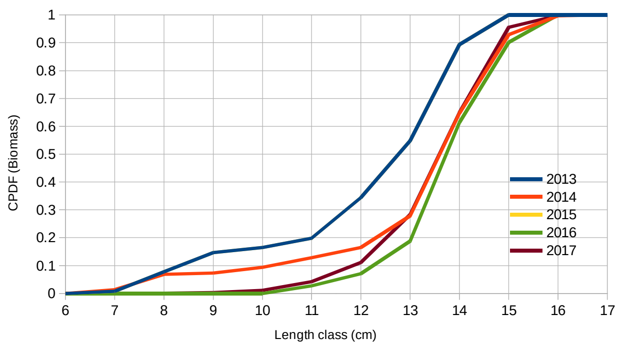
f)


Weight anomaly (g)
Year

g)


CPDF (Number)
Length class (cm)
2013
2014
2015
2016
2017

h)


CPDF (Biomass)
Length class (cm)
2013
2014
2015
2016
2017

i)

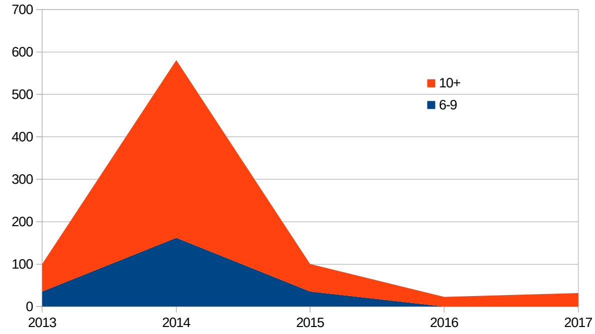


Figure 23: Boar fish stock descriptors (2013-17). a) Center of gravity along surveyed area and depth; b) map showing the number of the areas related in 10a; c) abundance and mean length estimates for the overall area; d) biomass and mean weight estimates for the overall area; e) mean length anomaly along years; f) mean weight anomaly ; g) length cumulated abundance; h) length cumulated biomass; and i) proportion of young (6-9 cm) and adult fish (10+cm).

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